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DFA-Tool Training and Assimilation Kit – Part-A

(For software RLS-09)

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1. Introduction

1.1 DFA-Tool hardware and software

This section deals with the top level DFA-Tool hardware and software.

1.1.1 DFA-Tool – Top-level system

The following Figure 1-1 depicts the DFA-Tool top level system.

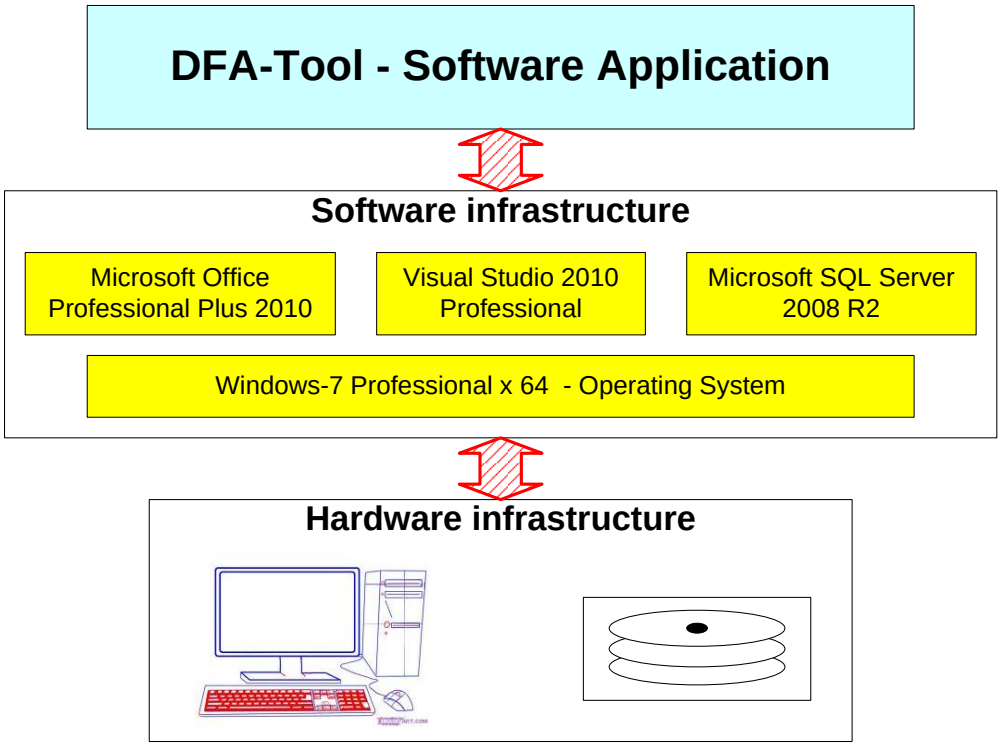

DFA-Tool - Software Application
Software infrastructure
Microsoft Office Professional Plus 2010
Visual Studio 2010 Professional
Microsoft SQL Server 2008 R2
Windows-7 Professional x 64 - Operating System
Hardware infrastructure

Figure 1-1 – DFA-Tool – Top-level system design

The following Table 1-1 and Table 1-2 depict the recommended hardware and software (users and developers) infrastructure for the DFA-Tool development, use and maintenance.

Table 1-1 - Recommended Hardware Specifications

#	Subject	Parameter
1.	Processor	Core i5 Processor (for high speed optimization processes)
2.	Main Memory	4 GB Main Memory
3.	Monitor	22" Monitor
4.	Hard Disk	500 GB

Table 1-2 - Recommended Software Specifications

#	Subject	Software	S/W developer
1.	Operating system	Windows 7 Professional x 64 (English), Microsoft	
2.	Database system	Microsoft SQL Server 2008 R2 Express Edition, Microsoft	
3.	Office software	Microsoft Office Professional Plus 2010, Microsoft	
4.	Database application	Visual Studio 2010 Professional, Microsoft	X
5.	Interface software	Telerik RadControls for WPF, Telerik	X
6.	Visual assist software	Visual Assist X v.10 for Visual Studio 2010, Whole Tomato Software	X
7.	Graphic software: (graph diagram)	Northwood.GoWPF, SKU: xamwpf, Northwoods Software Corporation	X
8.	Graphic Software: (3-D surface)	TBD	X
9.	Debugger	EurekaLog.NET 6 Enterprise for Visual Studio, EurekaLog	X
10.	Source Control	Subversion for Visual Studio (Server/Client), VISUALSVN	X

1.1.2 Notes - DFA-Tool hardware and software

1. The DFA-Tool is designed to be installed on a PC and run locally, as a standalone program. The tool is not being supported in a client-server configuration.
2. The hardware table should be viewed as a recommendation in order to achieve fast optimization processing. The Intel Core i3 is also an acceptable processor.
3. In order to accommodate users with older system versions, the DFA-Tool is written in a 32 Bit configuration. This means the tool is able to run under both 32 and 64 Bit systems but is somewhat slower (a restriction to the optimization process which require high processing speed). If funding allows, the tool will be regenerated also in a 64 Bit version.
4. The Microsoft SQL Server 2008 R2 Express Edition database system is available free of charge.
5. According to the AMISA proposal and the AMISA consortium agreement, the DFA-tool shall be free to all users and its software placed under open source licensing rules.

1.2 DFA-Tool operations and concepts

1.2.1 Operation scenario

Figure 1-2 depicts a typical DFA-Tool operation scenario.

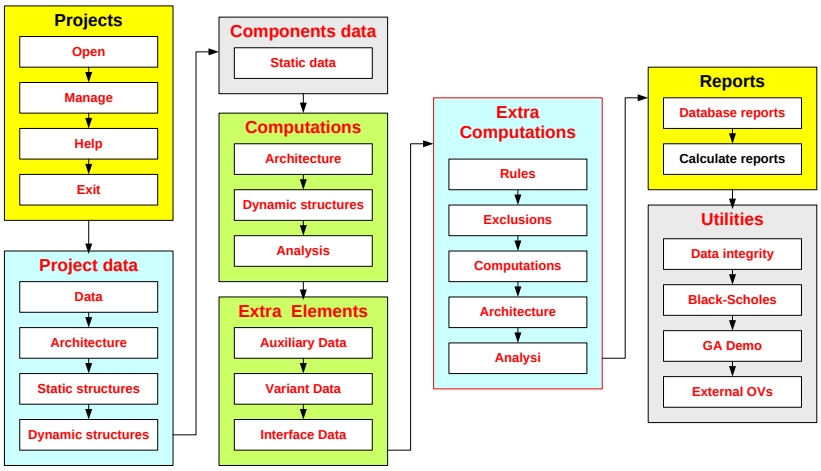


Figure 1-2 – DFA-Tool operation scenario

(Implemented functions are depicted in red**)**

1.2.2 Leaf components

The target system is composed of components organized in a hierarchical structure. We define "***Leaf components***" as the set of the lowest level components in the system, which are of interest to a particular system designer. Users of the DFA-Tool should note that computations of optimal adaptable architecture consider only leaf components and other elements (e.g. interfaces) associated with them. Other, higher level definitions, may be inserted into the database for the convenience of the user but are totally ignored by the optimization software.

1.2.3 Database integrity

DFA-Tool users should be aware that, in order to insure the integrity of the database, deletions of any database element can only be done hierarchically by removing the lowest elements first. The DFA-Tool software will resist attempts to delete a database element which is attached to a lower hierarchical level element. For example, a component having one or more son-component cannot be deleted until all the attached son-components are deleted. Likewise, a component attached to one or more interfaces cannot be deleted until all the attached interfaces are deleted. The hierarchical structure of the DFA-Tool database elements is depicted in Figure 1-3.

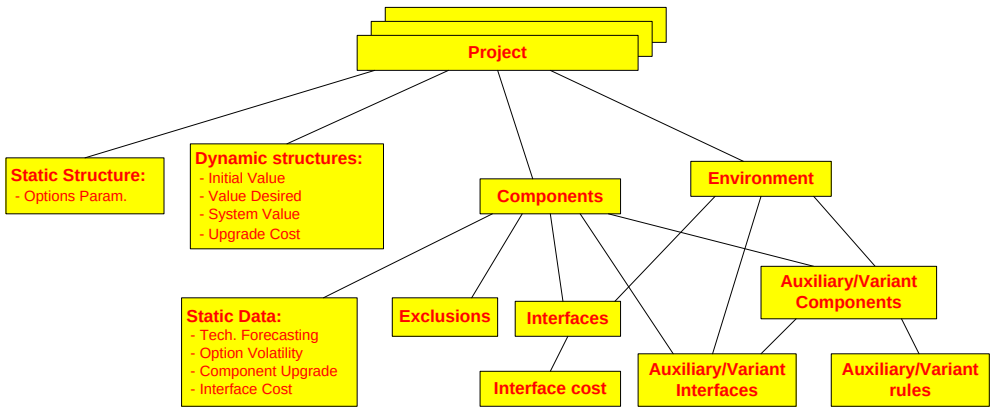


Figure 1-3 – Hierarchical structure of the DFA-Tool database

1.3 Top level view

Table 1-3 depicts the top two level elements of the DFA-Tool and their meaning.

Table 1-3 – DFA-Tool top elements

Name	Meaning
Projects	Identify an active project, manage projects, help users and exit the DFA tool
Project Data	Define project-wide input parameters
Component Data	Define component-level and Interface-level input parameters
Computations	Compute the output of the DFA tool and perform sensitivity analysis
Extra Elements	Define auxiliary and variant components/interfaces
Extra Computations	Calculate / analyze variant systems with auxiliary and variant components/interfaces
Reports	Generate reports of the input parameters and output results
Utilities	Provide various utilities

Figure 1-4 depicts the top two layers of the DFA-Tool Graphical User Interface (GUI). The meaning of each is explained later in this document (Implemented functions are depicted in red).

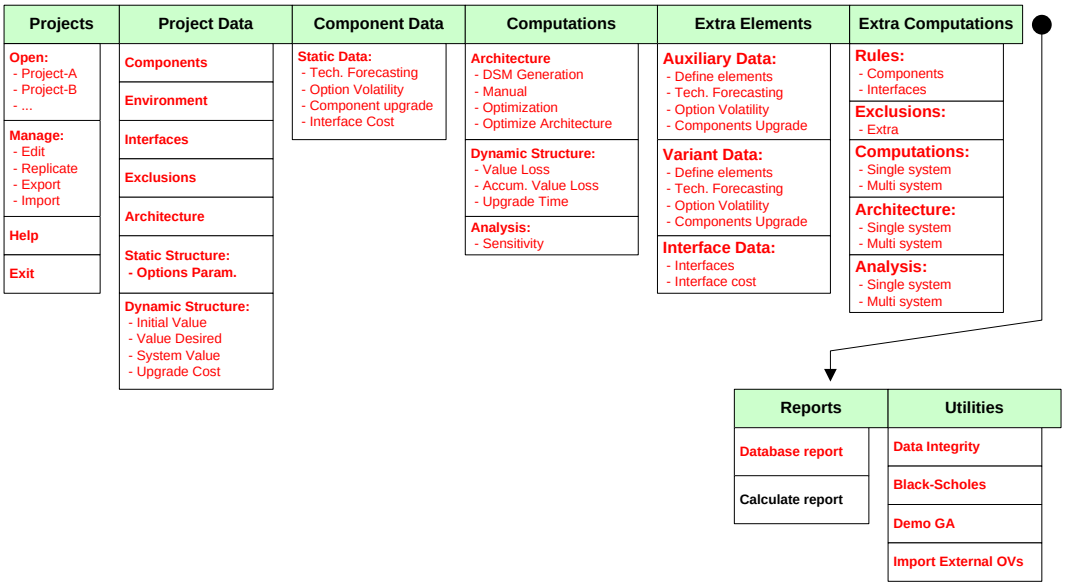


Figure 1-4 – DFA Tool – Top two GUI layers

2. Projects

The Projects section of the DFA-Tool consists of the following elements: (1) Open a project, (2) Manage projects, (3) Help services and (4) exit (see below).

2.1 Open a project

The Select a project GUI is depicted in Figure 2-1. The user can select any one of several defined and independent "Projects" within the DFA-Tool database. The project named "UAV-Example" is a general example, helping users understand the DFA-Tool. This project may be selected and modified but the users cannot delete the project nor modify its name. The Appendix at the end of this guide further describes this example.

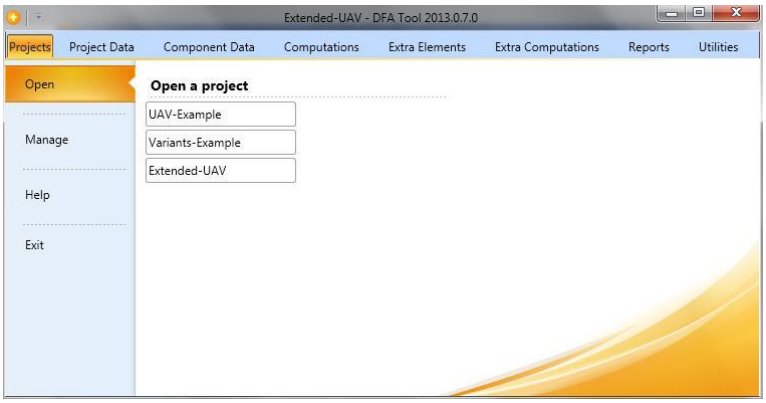


Figure 2-1 – Open a project GUI

2.2 Manage projects

The user can manage the database projects by performing the following functions: (1) Edit project, (2) Replicate project, (3) Export project and (4) Import project

2.2.1 Edit project

Figure 2-2 depicts the Edit project GUI. The user can modify the name of an existing project in the database or delete an existing project from the database. This may be done by clicking on the desired function (in this case: Edit) and then performing the required operation on the opened window and. The user should note that valid project names may only be composed of the following characters: "a-z", "A-Z", "0-9", "-", "_".

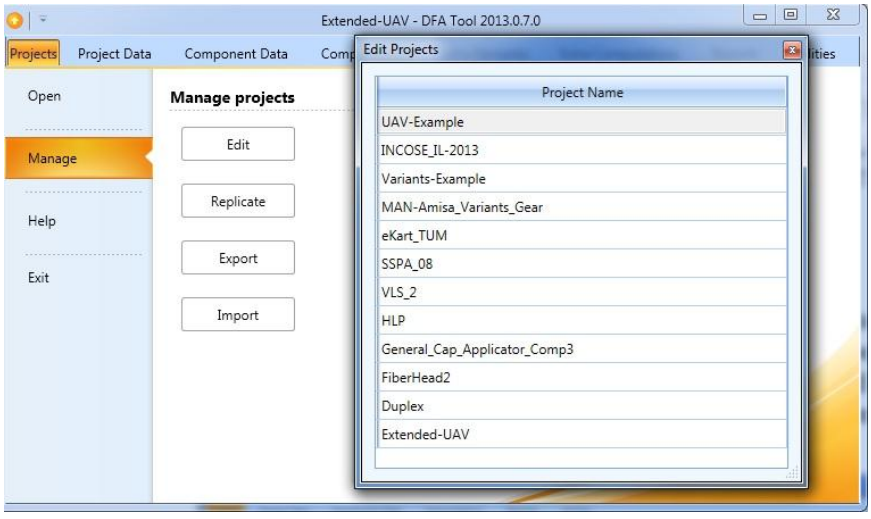


Figure 2-2 – Edit Project GUI

2.2.2 Replicate project

Figure 2-3 depicts the Replicate project GUI. Replicating a project is a process of copying the database of an existing project and saving it under a new name. This may be done by clicking on the desired function (in this case: Replicate) and then performing the required operation on the opened window. The user should note that valid project names may only be composed of the following characters: “a-z”, “A-Z”, “0-9”, “-“, “_”.

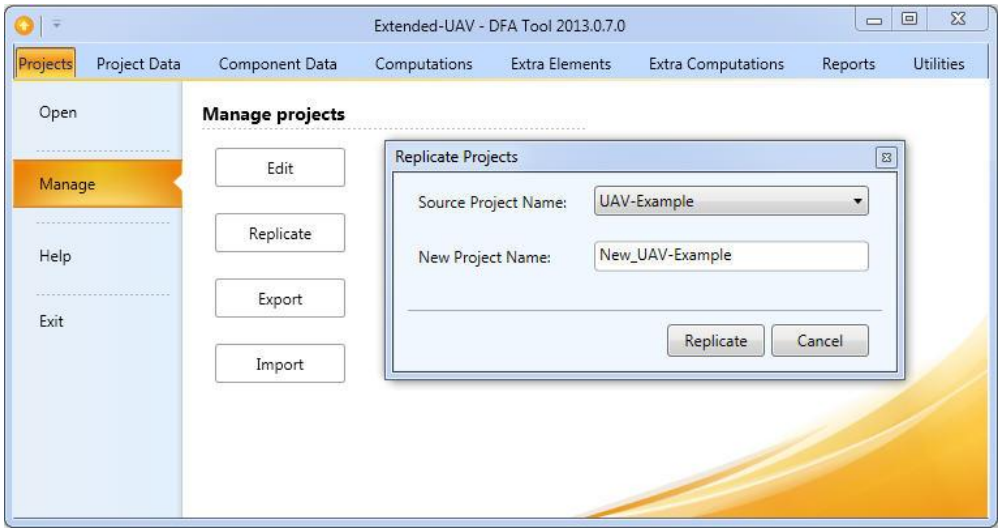


Figure 2-3 - Replicate Project GUI

2.2.3 Export project

Generate an XML file from a Project in the database for external use (follow the simple wizard steps).

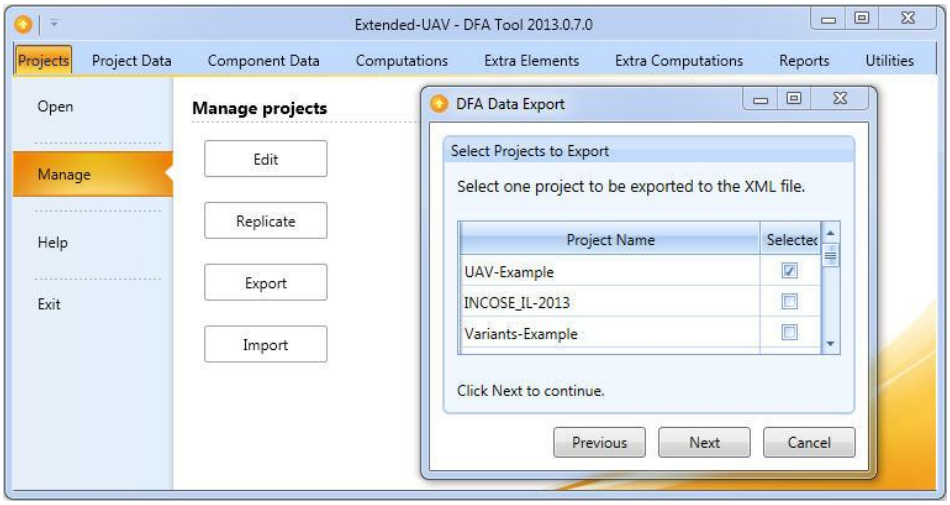


Figure 2-4 – Export Project GUI

Typical XML file appears below

```
<?xml version="1.0" encoding="utf-8" standalone="yes"?>
<Project ProjectName="UAV-Example">
  <Assembly Version="2012.0.0.4" />
  <Elements>
    <Element Abbreviation="UAV System" Name="Unmanned Air Vehicle"
Type="1">
      <Element Abbreviation="AS" Name="Air System" Type="1">
        <Element Abbreviation="AM" Name="Air Mission" Type="1" />
        <Element Abbreviation="PYLD" Name="Payload" Type="1" />
        <Element Abbreviation="AV" Name="Air Vehicle" Type="1" />
        <Element Abbreviation="AC" Name="Air Comm." Type="1" />
      </Element>
```

Figure 2-5 – Partial XML example

2.2.4 Import project

Create a Project in the database from an existing external XML file (follow the simple wizard steps).

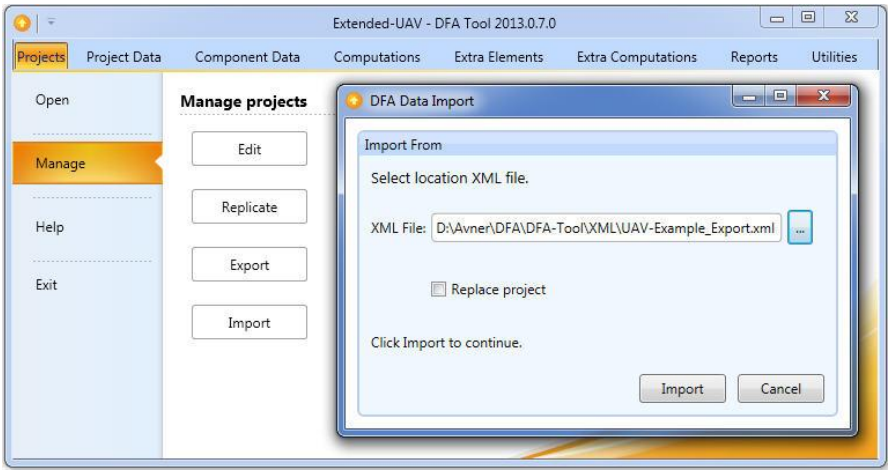


Figure 2-6 - Import Project GUI

2.3 Help services

The user guide (i.e. DFA-Tool Training and Assimilation Kit – Part-A) is available to the DFA-Tool users on line. Pressing an "F1" button will bring a relevant portion of the user guide associated with current functionality of the DFA-Tool.

For example, Figure 2-7 depicts a state where the user is working on the DFA-Tool Interface definition. The user needs help relevant to the Interface functionality. He clicks the "F1" button and a new window opens up showing Interface information extracted from the user guide. The right side of the window provides the actual user guide help and the left side of the window allows the user to browse freely throughout the user guide.

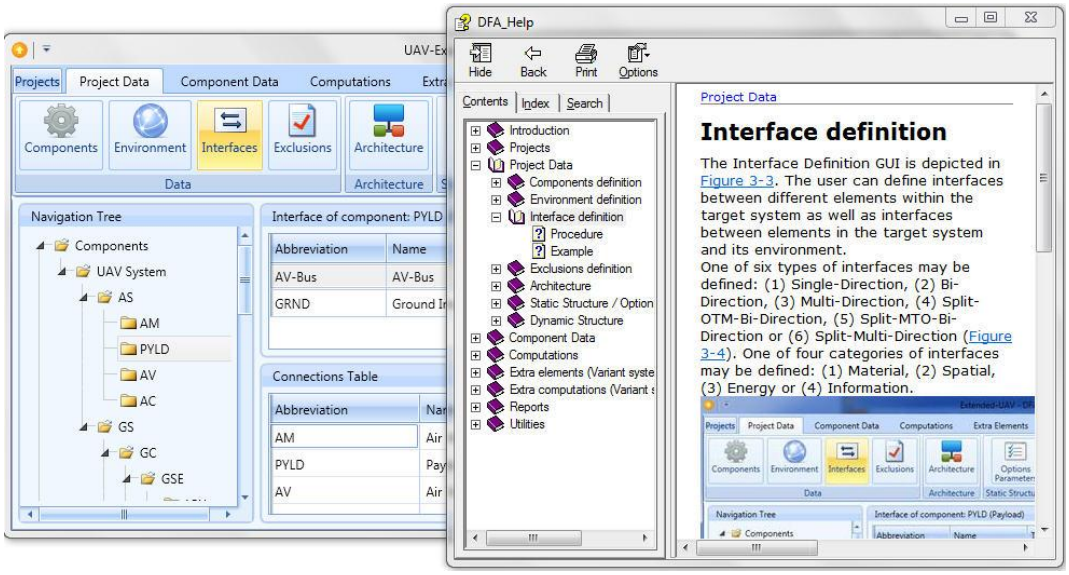
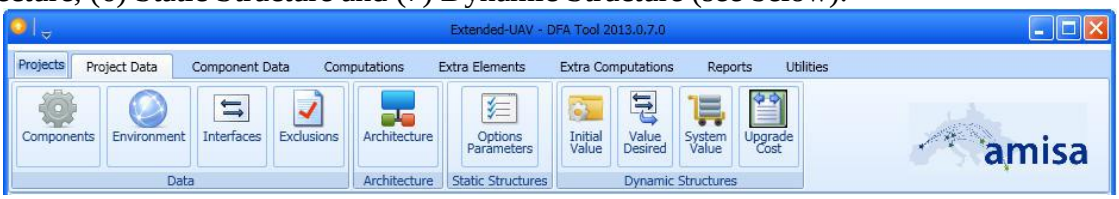


Figure 2-7 – Example of using the Help facility

3. Project Data

The purpose of this portion of the DFA-Tool is to support the project-wide input facility within the DFA-Tool. This section of the DFA-Tool consists of the following elements: (1) Components Definition, (2) Environment Definition, (3) Interface Definition, (4) Exclusions Definition, (5) Architecture, (6) Static Structure and (7) Dynamic Structure (see below).



3.1 Components definition

The Components Definition GUI is depicted in Figure 3-1. The user can define the target system composition in a top-down manner[1]. The actual implementation of the user interface with a tree structure of components follows the standard Microsoft interface for a file manager and similar software systems. This hierarchical decomposition implementation is a widespread method employed by systems engineers to analyze systems.

[1] The reader should note that only the system leaves-components (the lowest leaves of the system, which interest the designer) are relevant for the structural optimization of the target system.

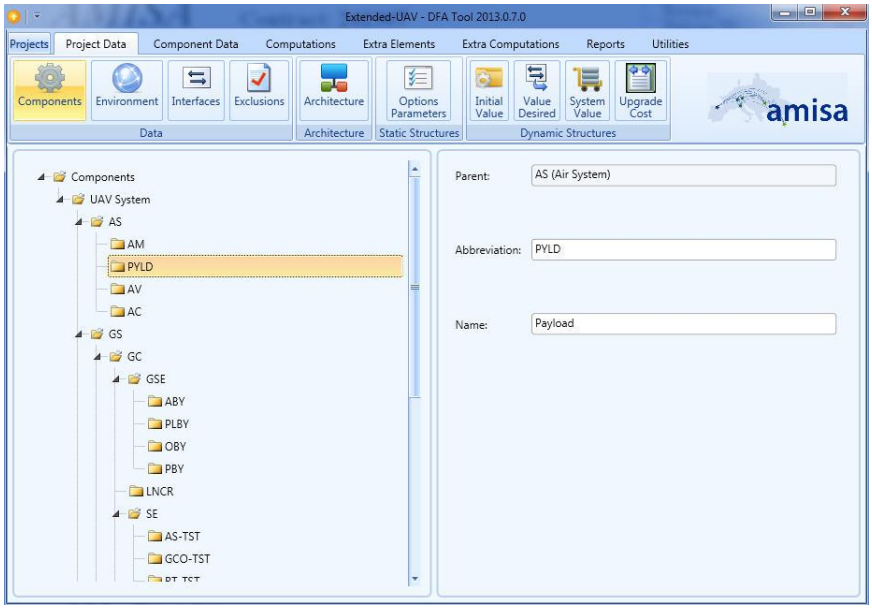


Figure 3-1 – Components definition

3.1.1 Procedure

- Focusing (clicking) on a component element shows the parent name as well as the components' abbreviated and full name.
- Right clicking on any component name provides menu to: (1) Expand and contract all the components tree-view and (2) Add son-components or modify or delete a component.
- Deletions of an element must adhere to the hierarchical rules, protecting the database (See Section 1.2.3).

3.1.2 Example

The example depicted in Figure 3-1 identifies a component element named PYLD (Payload) with a father named AS (Air System).

3.2 Environment definition

The Environment Definition GUI is depicted in Figure 3-2. Similarly to the Components Definition GUI, the user can define the systems' environment in a top-down manner.

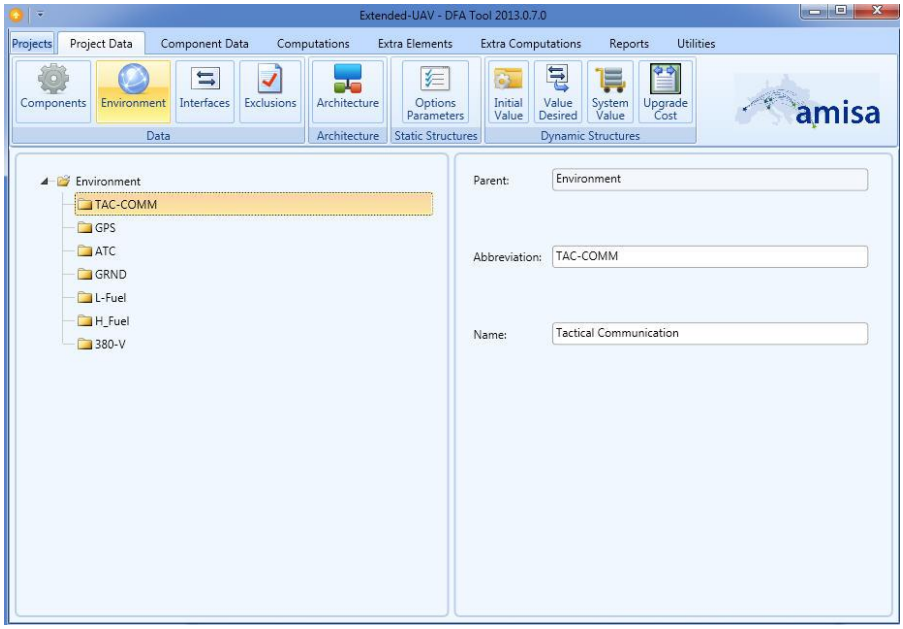


Figure 3-2 – Environment Definition

3.2.1 Procedure

- Focusing (clicking) on an environment element shows the parent name and the environments' abbreviated and full name.
- Right clicking on any environment name provides menu to: (1) Expand and contract all the environment tree-view and (2) Add son-environment or modify or delete an environment name.
- Deletions of an environment element must adhere to the hierarchical rules, protecting the database (See Section 1.2.3).

3.2.2 Example

The example depicted in Figure 3-2 identifies an environment element named TAC-COMM (Tactical Communication) with a father named Environment.

3.3 Interface definition

The Interface Definition GUI is depicted in Figure 3-3. The user can define interfaces between different elements within the target system as well as interfaces between elements in the target system and its environment.

One of six types of interfaces may be defined: (1) Single-Direction, (2) Bi-Direction, (3) Multi-Direction, (4) Split-OTM-Bi-Direction, (5) Split-MTO-Bi-Direction or (6) Split-Multi-Direction (Figure 3-4). One of four categories of interfaces may be defined: (1) Material, (2) Spatial, (3) Energy or (4) Information.

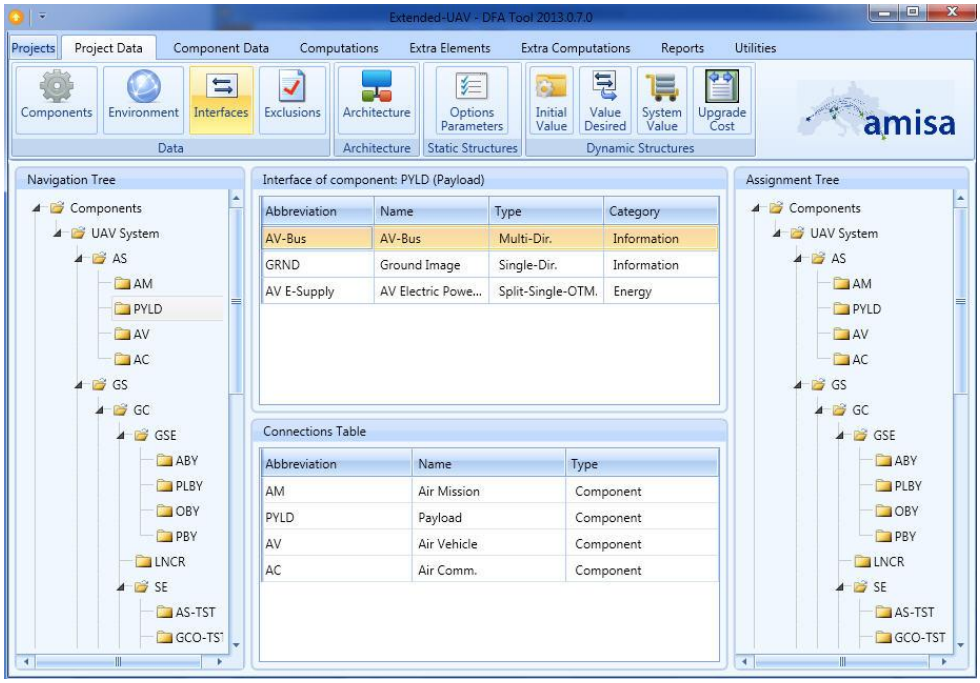


Figure 3-3 – Interface definition

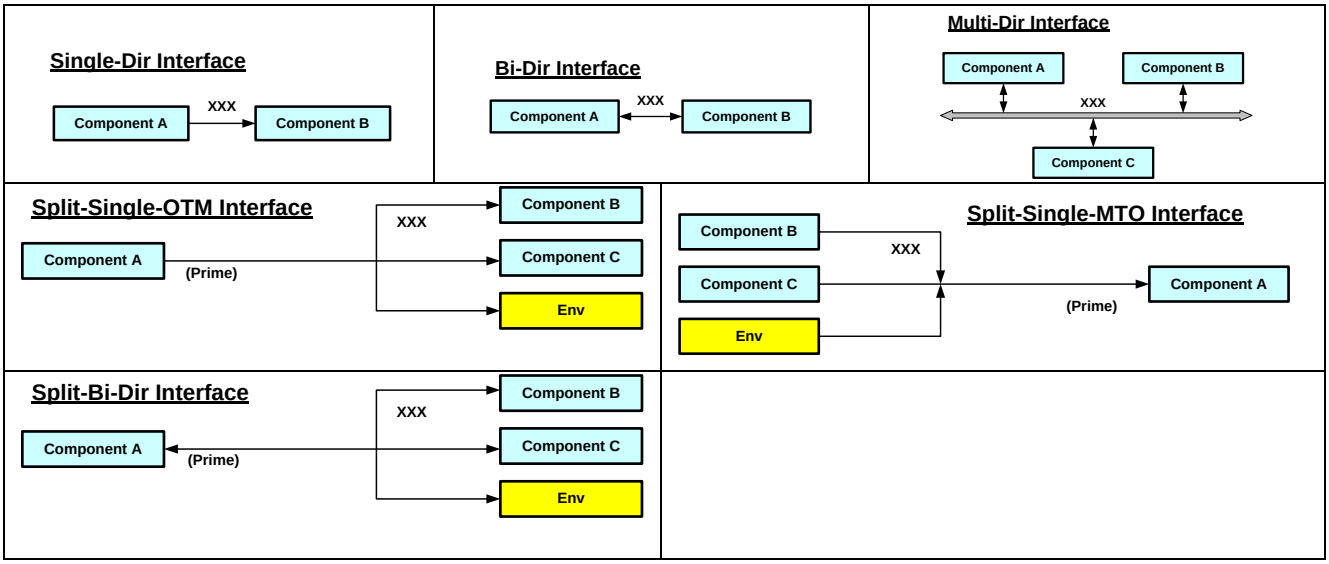


Figure 3-4 – Six types of interfaces

3.3.1 Procedure

The procedure to Add/Modify/Delete an interface is carried out following these steps:

- Step-1: Use the Navigation tree on the left hand side of the display to select an element for which an interface should be defined.
- Step-2: Right click on the Interface Table and select the desired action (Add, Modify, Delete)

- Step-3: Assuming an Add interface is the action desired. The user should define the abbreviation and full name of the interface as well as the type of interface and the category of interface.
- Step-4: The connection table, automatically select one connection from the identified Navigation tree.
- Step-5: If the type of interface is a Single-Direction or Split Single-Direction, then the user must specify the direction of the connection (Source or Destination) in the connection table. Bi-Direction or Multi-Direction do not need this information.
- Step-6: When a Split interface is defined, the first specified element becomes the prime side of the interface.
- Step-7: The user uses the Assignment Tree on the right in order to add additional connection into the connection table. Single-Direction and Bi-Direction interfaces require exactly two connections whereas all the other interfaces may have two or more connections.
- Deletions of an interface or a connection must adhere to the hierarchical rules, protecting the database (See Section 1.2.3).

3.3.2 Example

The example depicted in Figure 3-3 identifies a Multi-Direction interface named AV-Bus (AV-Bus) of category Information. It connects the AM (Air-Mission), PYLD (Payload), AV (Air-Vehicle) and AC (Air-Comm.) Components.

3.4 Exclusions definition

The Exclusion sets definition GUI is depicted in Figure 3-5. The user can define mutually exclusive sets of components, within the target system. Components from mutually exclusive sets cannot reside within a single module and therefore, may interact only by means of an interface. Of course, a given component cannot appear in two sets.

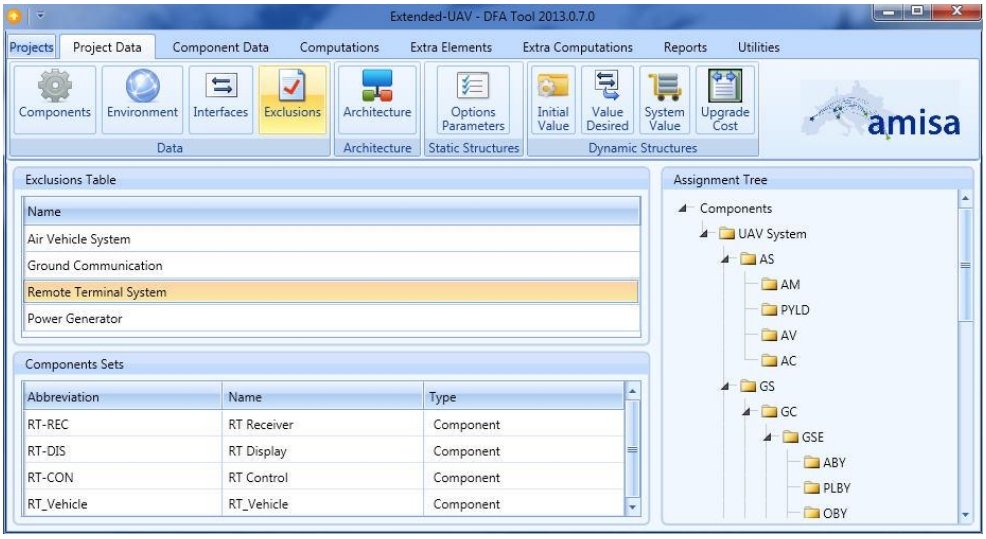


Figure 3-5 – Exclusions definition

3.4.1 Procedure

The procedure to Add/Modify/Delete an Exclusion set is carried out following these steps:

- Step-1: Right click on the Exclusion Table and select the desired action (Add, Modify, Delete).
- Step-2: Assuming an Add Exclusion set is the action desired. The user should firstly define the name of the exclusion set.
- Step-3: Next, the user clicks on the Components Sets table and then clicks on a selected component from the assignment Tree in order to add it into the Exclusion set.
- Step-4: This process (Step-3 alone or Step-1 to Step-3) may be repeated as needed.

3.4.2 Example

The example depicted in Figure 3-5 identifies four exclusive sets of components within an Unmanned Air Vehicle (UAV) System. The three Exclusive sets are: (1) the Air Vehicle system, (2) Ground communication, (3) Remote Terminal and (4) Other system components. In particular, the Remote Terminal System set is composed of the following components: RT-REC (RT Receiver), RT-DIS (RT Display) and RT-CON (RT Control).

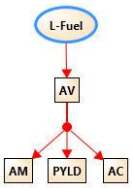
3.5 Architecture

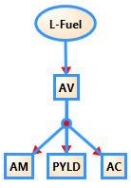
The user can generate graphical charts of the project architecture.

3.5.1 Procedure

The procedure to generate graphical charts of the project architecture is done following these steps:

- Step-1: Select the desired interface category. If the system is complex and contains multi-interface types, the users should generate architecture charts for each type of interface.
- Step-2: If an architecture chart is saved from a previous session then the user can show it by clicking the "Show" button. Note that saved architecture charts may not be valid if relevant database parameters have been modified.
- Step-3: Click on the "Build" button. The raw architecture will be displayed (Often a maximal window is preferable). The detail of each architecture chart is depicted in the blue strip just above the chart.
- Step-4: The user can edit the architecture chart by identifying and moving individual or groups of symbols of components, environments or splitting points of interfaces.





- Step-5: The user can "Save" the edited chart and later "Show" a saved architecture chart by clicking the relevant buttons.
- Step-6: Also the user can change the "Scale" of the image using the slide at the bottom-left.

- Step-7: The user can select an object (i.e. Components, Environment or Interface) and click on the "Parameter" tab. A window will slide open revealing the parameters associated with the selected object.

3.5.2 Example

- Figure 3-6 depicts a "Raw", "Combined" architecture of the UAV system.

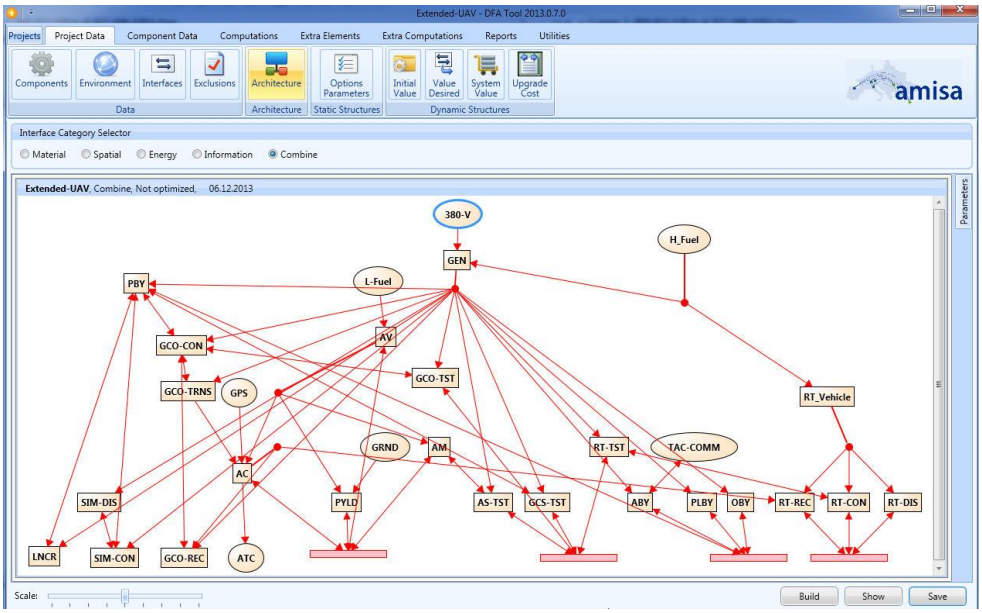


Figure 3-6 – Raw "Combined" architecture - UAV system

- Figure 3-7 depicts the edited "Information" architecture of the UAV system. Note the "unconnected" components or interfaces in each view.

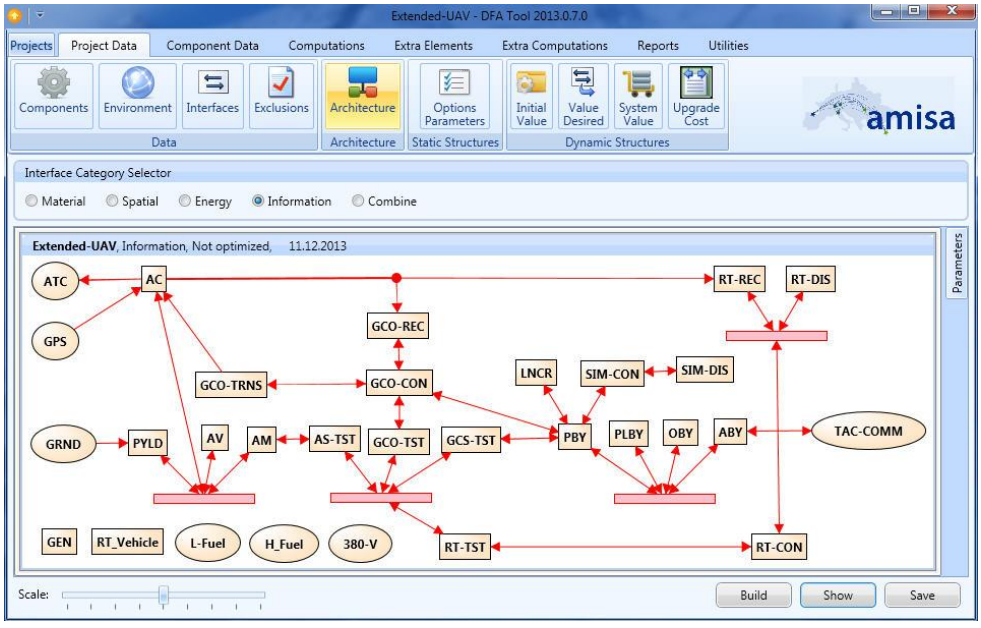


Figure 3-7 - Edited "Information" architecture - UAV system

- Figure 3-8 depicts the same information. Here, a component is selected and the "Parameters" window is open revealing the parameters associated with the selected component.

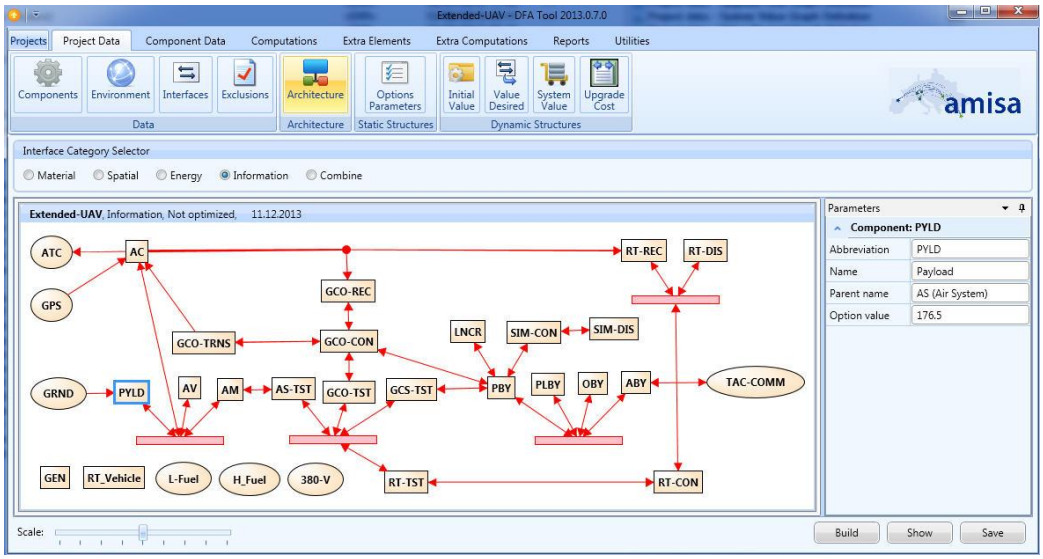


Figure 3-8 – Component and parameter information window

- Figure 3-9 depicts the corresponding edited "Energy" architecture. Note the "unconnected" components or interfaces in each view.

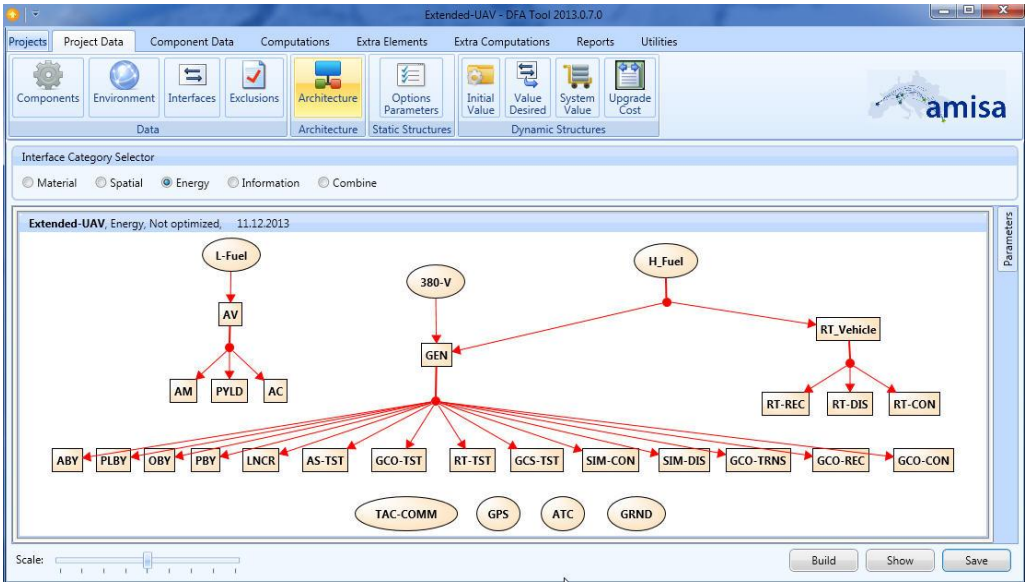


Figure 3-9 - Edited "Energy" architecture - UAV system

3.6 Static Structure / Option Default Parameters

The context of the Option Default Parameters is depicted in Figure 3-10. The actual user GUI is depicted in Figure 3-11. The user can define the following project-level defaults: (1) Time [Years] to update the system and (2) Risk-free interest rate [%] for updating the target system. These two parameters are used in the Black-Scholes Options Value (OV) equation.

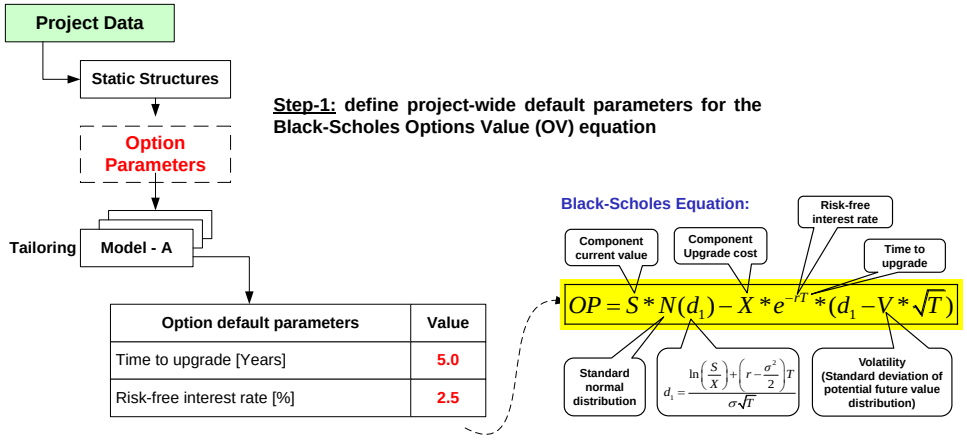


Figure 3-10 – Context of the Options Default Parameter

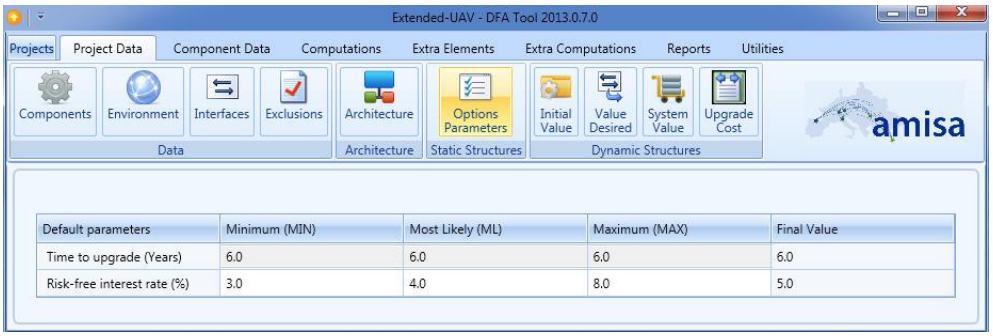


Figure 3-11 - Options default parameter GUI layout

3.6.1 Procedure

The procedure to define a project-level Options Default Parameters is carried out as follows:

Right click on any of the two default parameters (i.e. Time to upgrade, Risk-free interest rate) and define the relevant parameters. For each parameter, the user should insert three records: (1) a Minimum, (2) a Most likely and (3) a Maximum values. Such three valued sets are essentially, triangular distributions of estimated values. The DFA-Tool computes each center of gravity of these imaginary triangles which constitute the appropriate parameters for the Black-Scholes Options Price (OP) equation.

3.6.2 Example

The example depicted in Figure 3-11 identifies a Time to upgrade data set of: MIN=ML=MIN=5 years, and the final computed parameter is 5 years. Similarly, the Risk-free interest rate set is given as: MIN=2.0%, ML=2.5% and MAX=3.0% with a final computed parameter of 2.5%.

3.7 Dynamic Structure

The Dynamic modeling of system lifecycle value and value-loss is depicted in Figure 3-12. Essentially all system provides value to stakeholders. This value starts at an Initial system Value (ISV). However, the value of systems tends to diminish due to: (1) Hardware and software Wear-out

Costs (WC) and (2) Components & infrastructure Obsolescence Costs (OC). At the same time, stakeholders tend to desire improved systems over time. This is mostly due to: (1) Expected Economic Growth (EG) and (2) Technological Advances (TA). Our purpose in the dynamic structure portion of the DFA-Tool to determine optimal upgrade time of the system.

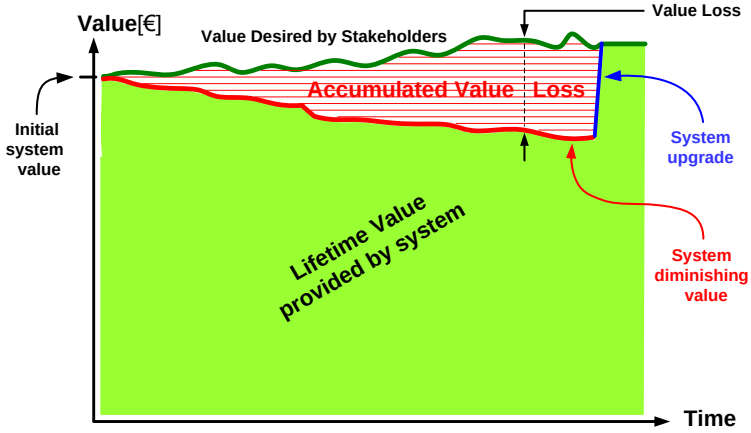


Figure 3-12 – System value and value loss

The following subsections describe the essential data required in order to estimate the optimal upgrade time of the system: (1) Initial system value, (2) Value desired, (3) System value and (4) Upgrade cost

3.7.1 Initial system value

Figure 3-13 depicts initial values needed for, eventually, estimate the system upgrade time. This includes two aspects:

1. **Definitions of the relevant time-horizon.**

The user can specify the units (Months or Years) and their number. The allowable range of Months or Years is 0-150. For example, in the figure below, the selected time-horizon is 10 Years.

2. **Definitions of the Initial System Value (ISV).**

The user can specify the Initial System Value (ISV) using a triangular distribution. For example, in the figure below the ISV is defined as €130M (Minimum=€100M, Most likely=€110M and Maximum=€180M)

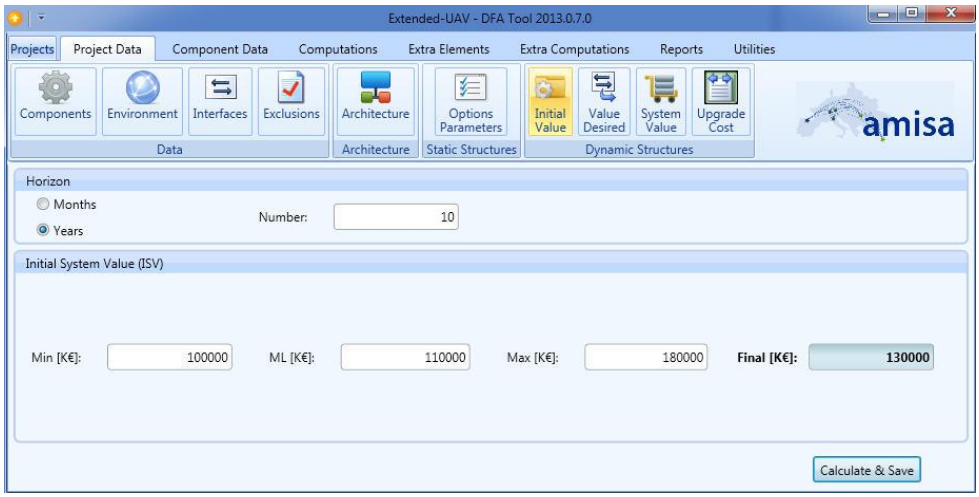


Figure 3-13 – Initial System Value (ISV) GUI

3.7.2 Value desired

Figure 3-14 and Figure 3-15 depict the expected system value desired by stakeholders. The user specifies four parameters using a triangular distribution. These parameters are:

1. Yearly slope of the expected Economic Growth (EG)
2. Yearly volatility of the expected Economic Growth (EG)
3. Yearly slope of the expected Technology Advances (TA)
4. Yearly volatility of the expected Technology Advances (TA)

The relationships are expressed via the following equation:

$$\boxed{VD(t) = ISV + f_{EG}(t) + f_{TA}(t)}$$

As can be seen in the figure below, the desired system value starts at the Initial System Value (ISV) and increases, more or less linearly, due to increases in the expected Economic Growth (EG) and expected Technology Advances (TA). For example, in the figure below, the yearly slope and yearly volatility of the expected EG are 1% and 5% correspondingly. The yearly slope and yearly volatility of the expected TA are 3% and 8% correspondingly.

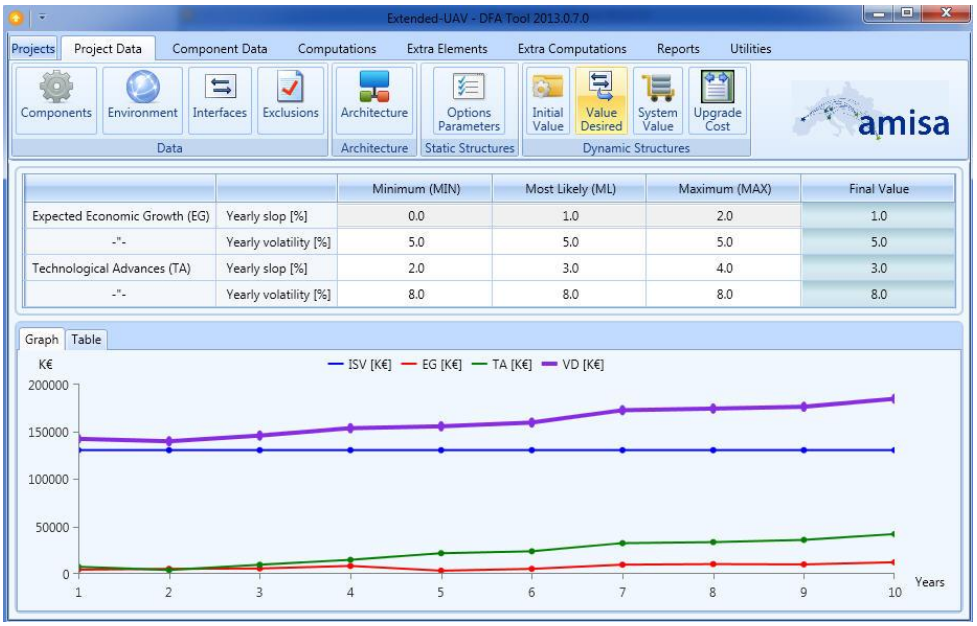


Figure 3-14 – Value Desired GUI – Graph representation

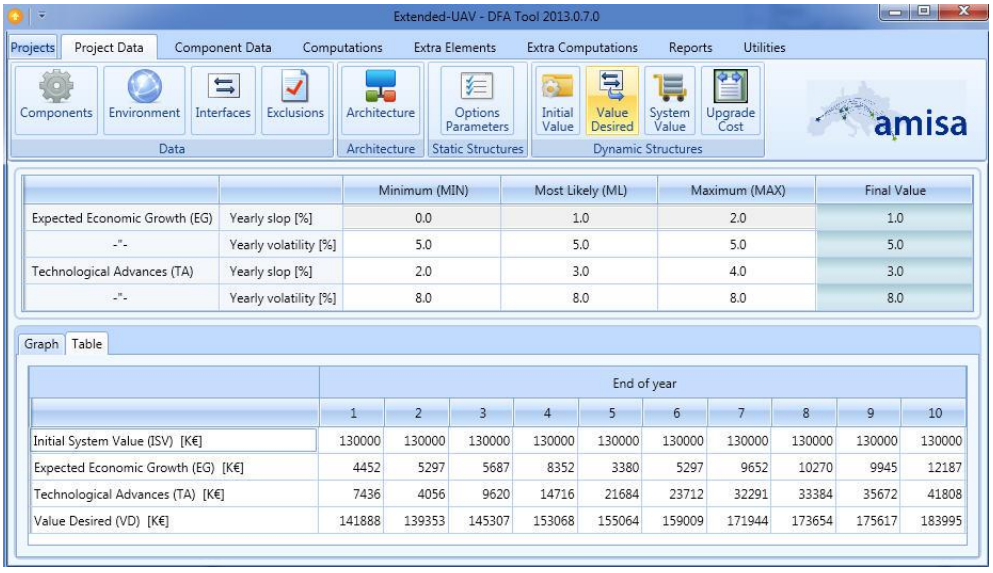


Figure 3-15 - Value Desired GUI – Table representation

3.7.3 System value

Figure 3-16 depicts the expected system value over time. The user specifies four parameters using a triangular distribution. These parameters are:

1. Yearly slope of the expected Wear-out Cost (WC)
2. Yearly volatility of the expected Wear-out Cost (WC)
3. Yearly slope of the expected Obsolescence Cost (OC)

4. Yearly volatility of the expected Obsolescence Cost (OC)

The relationships are expressed via the following equation:

$$SV(t) = ISV - \left(f_{WC}(t) + f_{OC}(t) \right)$$

As can be seen in the figure below, the desired system value starts at the Initial System Value (ISV) and decreases, more or less linearly, due to increases in the expected Wear-out Cost (WC) and expected Obsolescence Cost (OC). For example, in the figure below, the yearly slope and yearly volatility of the expected WC are 3% and 5% correspondingly. The yearly slope and yearly volatility of the expected OC are 1% and 8% correspondingly.

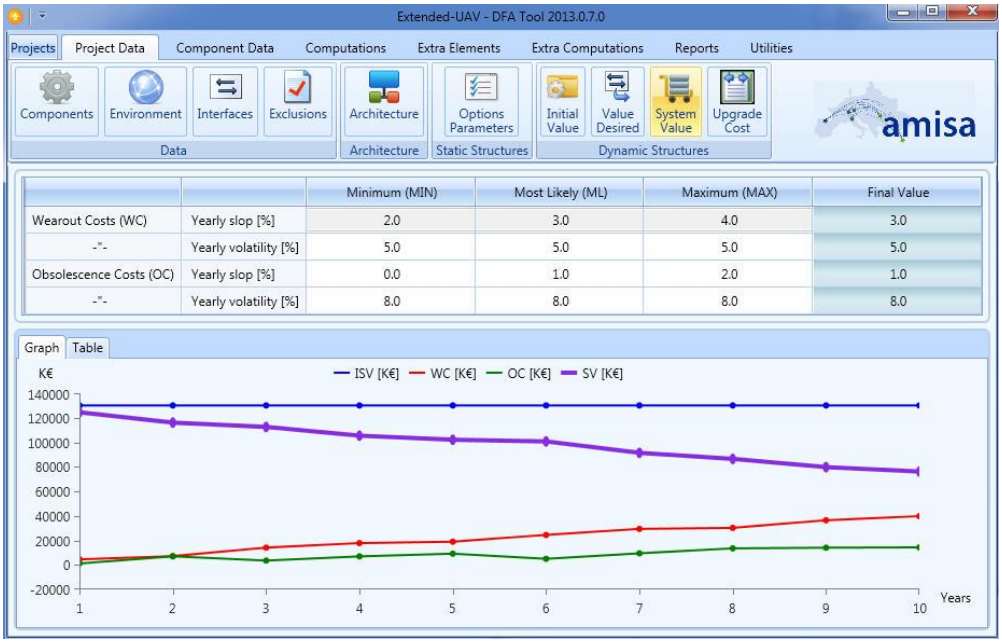


Figure 3-16 – System Value GUI

3.7.4 Upgrade cost constant (UCC)

Figure 3-17 defines the Upgrade Coat Constant (UCC), which is a percentage of the Initial System Value (ISV). The user specifies this constant using a triangular distribution.

The DFA-Tool shows (1) Value loss (VL) and (2) Initial System Value (ISV). In addition, based on this constant, it calculates and shows the Upgrade cost (UC).

The relationships are expressed via the following equation:

$$UC(t) = UCC * ISV + VL(t)$$

For example, in the figure below, the UCC is 50% of the ISV. Since ISV = €130K, then initially the system upgrade cost starts at €65K. This upgrade cost increases over time due to increase in Value Loss (VL). In other words, we model the upgrade cost increases due to the stakeholders increased expectations coupled with the diminishing value of the system.

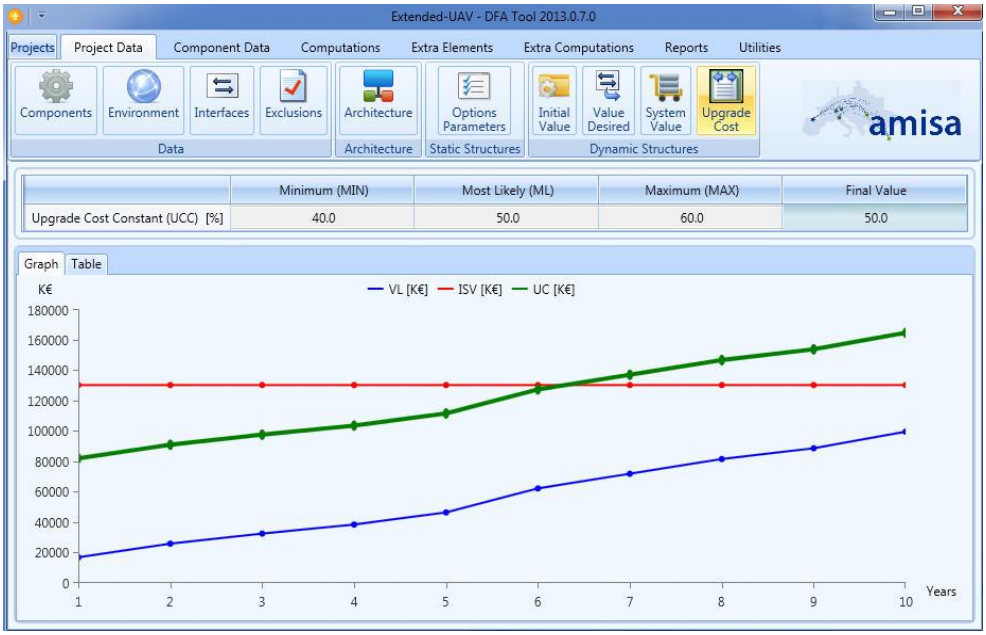
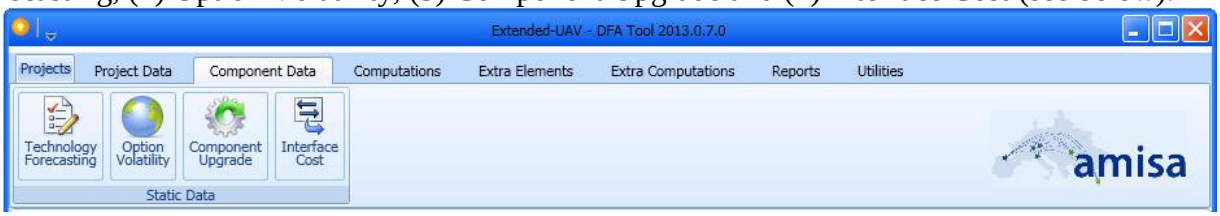


Figure 3-17 – Upgrade Cost GUI

4. Component Data

The purpose of this portion of the DFA-Tool is to support the component-level input facility within the DFA-Tool. This section of the DFA-Tool consists of the following elements: (1) Technology Forecasting, (2) Option Volatility, (3) Component Upgrade and (4) Interface Cost (see below).



4.1 Technology forecasting

The defined technology forecasting laws are depicted in Figure 4-1. The component-level Technology Forecasting GUI is depicted in Figure 4-2. Firstly, the user must decide whether to use the "Total" data entry mode or the "Detailed" data entry mode. Under the Total entry scheme, the user may enter one positive value (including 0) as the estimated technology forecasting. Under the detailed data entry mode, the user can define the selected Technology Forecasting laws and provide means to insert the relevant information so the DFA-Tool can compute the expected future value (S') and the expected future value gain (S'-S) of the given component.

#	Forecasting Laws	#	Forecasting Laws (Cont.)
1	System convergence	12	Action coordination
2	Similar systems merging	13	Space coordination
3	Convoluted system merging	14	Parameters coordination
4	Alternative system merging	15	Controllability
5	Integration of inverse systems	16	Dynamization
6	Integration of disparate systems	17	Transition to super system
7	Combining multiple systems	18	Increasing system completeness
8	Flow conductivity	19	Displacement of human
9	Shape/Form coordination	20	Uneven system development
10	Timing and rhythm coordination	21	Technology general progress
11	Materials coordination		

Figure 4-1 – Defined technology forecasting laws

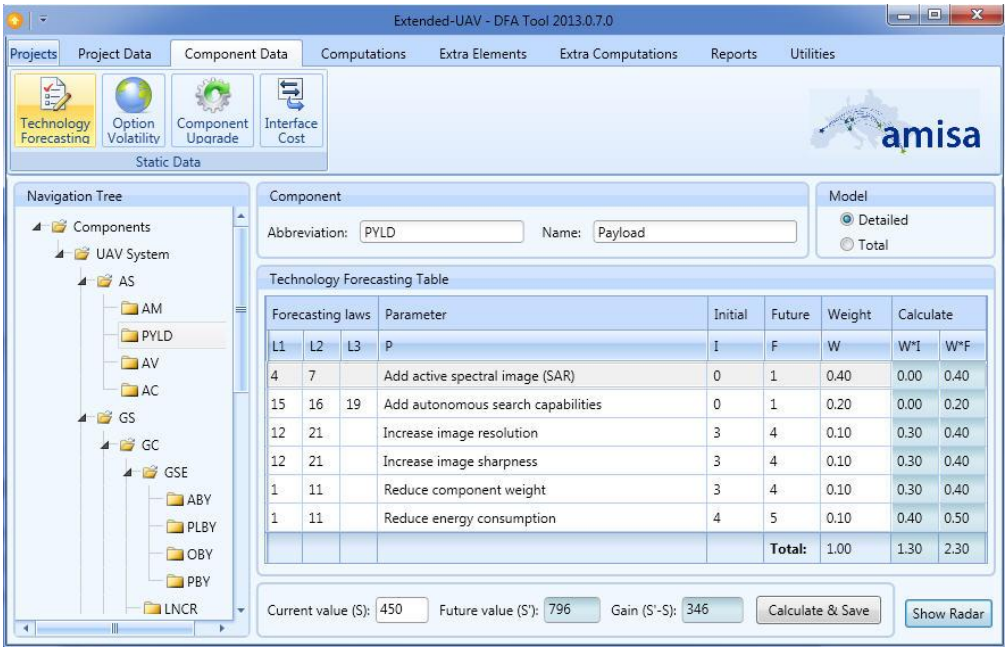


Figure 4-2 – Technology Forecasting data

4.1.1 Procedure

The procedure to Add/Modify/Delete component-level Technology Forecasting data is carried out following these steps:

- Step-1: Right click on the relevant component in the navigation tree and select the desired action (Add, Modify, Delete).
- Step-2: The user must define the model of data entry either “Detailed” (as will be explained below) or “Total” in which the user can enter directly any value (including 0)
- Step-3: Assuming an add Technology Forecasting data is the action desired. The user should firstly add a new entry in the Technology Forecasting Table. Also the user can ask for more information related to TRIZ rules on systems evolutionary laws.
- Step-4: Insert the name or a short description of the parameter which is expected to evolve in the future.

- Step-5: Right-click on up to three forecasting laws, identifying the forecasting law(s) which are expected to govern the evolution of the relevant parameter.
- Step-6: Identify the initial and the expected final level of component technology.
- Step-7: Insert a weight factor for each parameter. The DFA-Tool expects the sum of all the weights to be equal 1.00.
- Step-8: Continue this process (Step-2 to Step-6) appropriately.
- Step-9: The DFA-Tool will compute the derived multiplications and sums ($\sum I_i*W_i$; $\sum F_i*W_i$).
- Step-10: Insert the current value of the component and the DFA-Tool will calculate the expected future value (S') and the expected future value gain (S'-S) of the given component.

Note-1: The user can place the cursor on the different identifiers of the Technology Forecasting Laws (1-21) and the DFA-Tool will display the relevant names of the laws.

Note-2: If the number of forecasting parameters exceeds two, the user can ask for a Radar chart in order to visualize the expected technical gains.

4.1.2 Example

The example depicted in Figure 4-2 identifies six parameters affecting future technology advances relevant to the Payload (PYLD) of the UAV system, together with its relevant Technology Forecasting laws (See Figure 4-1). Based on the data in the table and the current component value S=€450K, the expected future value of the component is S'= €796K and the gain is S'-S= €346K. Figure 4-3 depicts a Radar chart of initial, expected and final component-levels technology.

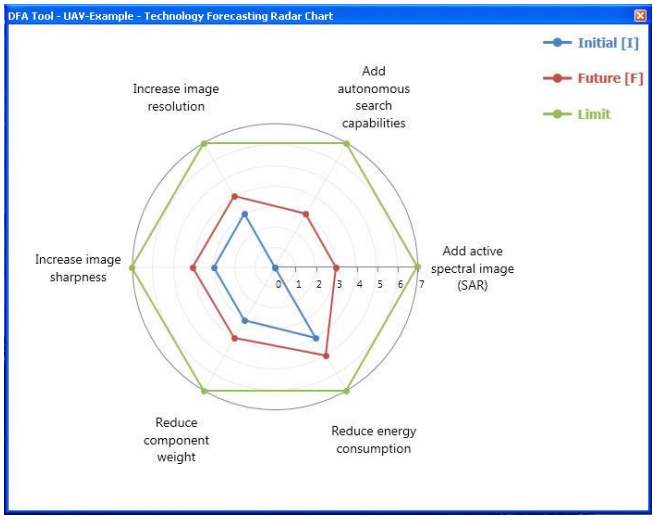


Figure 4-3 – Radar chart – Future component technology prediction

4.2 Option Volatility

The component-level Option Volatility value is depicted in Figure 4-4. The user can insert the volatility factor of the given component so the DFA-Tool can compute the Option Value (OV) and the distribution of the expected component's results.

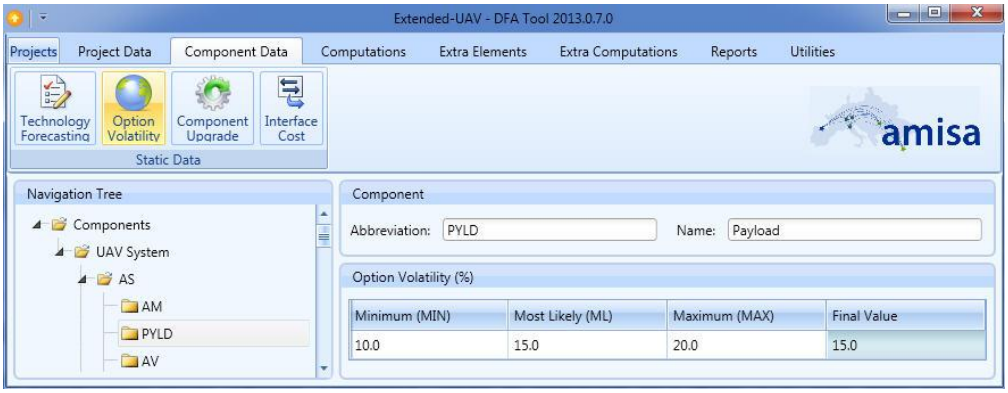


Figure 4-4 - Components' Option Volatility GUI layout

4.2.1 Procedure

The procedure to Add/Modify/Delete a component-level Technology Forecasting data is carried out following these steps:

- Step-1: Right click on the relevant component in the navigation tree and select the desired action (Add, Modify, Delete).
- Step-2: Assuming an add Option Volatility data is the action desired. The user should insert three records: (1) a Minim, (2) a Most likely and (3) a Maximum values. This is essentially a triangular distribution of estimated Option Volatility values. The DFA-Tool will compute the center of gravity of this imaginary triangle which is the representative result.

4.2.2 Example

The example depicted in Figure 4-4 identifies an Option Volatility data set of the PYLD (Payload): MIN=10%, ML=15% and MAX=20%. The final value of the Option Volatility is calculated to be 15%.

4.3 Component Upgrade

The user can use one of two Component Upgrade insertion schemes. Accordingly, the user may employ the Component Upgrade cost depicted in Figure 4-5 ("Detailed" scheme) or the Component Upgrade cost depicted in Figure 4-6 ("Total" scheme). The user will then insert the relevant information and the DFA-Tool will compute the overall upgrade cost for the given component.

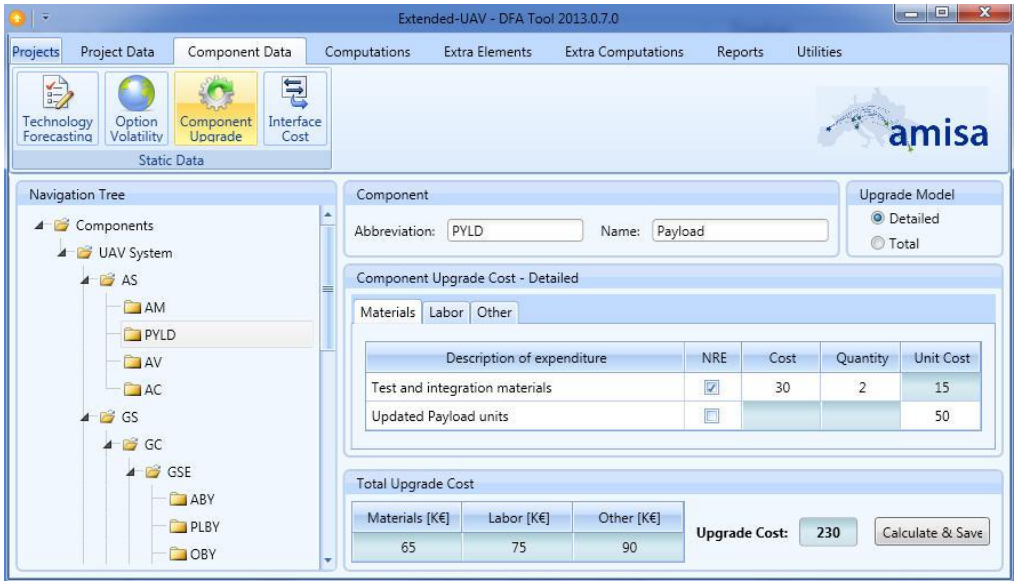


Figure 4-5 – Component upgrade cost computation – Detailed

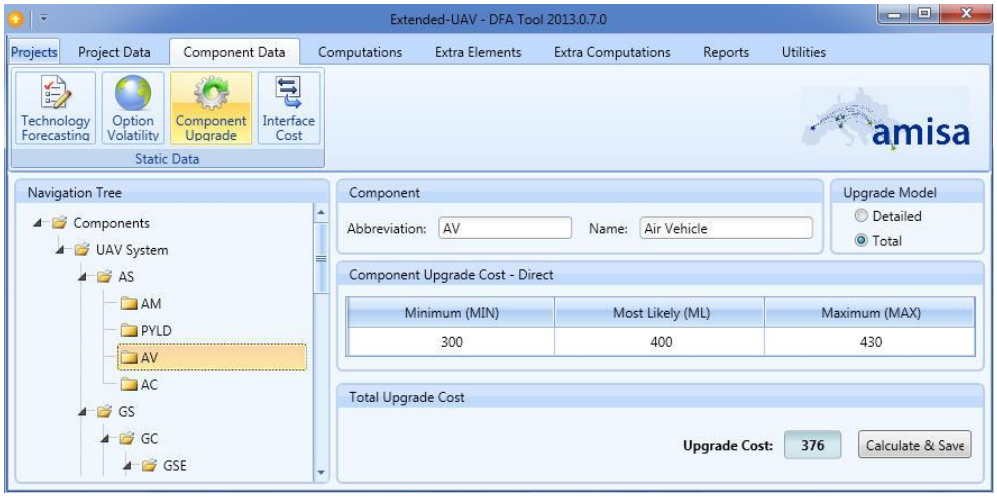


Figure 4-6 – Component upgrade Cost computation - Total

4.3.1 Procedure

The following procedure defines the manner for defining upgrade cost insertion in a detailed way:

- Step-1: Right click on the relevant component in the navigation tree.
- Step-2: In the upgrade model box select radio button “Detailed”.
- Step-3: Right click to add Component Upgrade Entry.
- Step-4: Select tab “Materials”.
- Step-5: Right click to add Detailed Component Upgrade Entry
- Step-6: Add text describing the upgrade expenditure

- Step-7: If this not a Non-Recurring (NRE) expenditure, insert the relevant unit cost
- Step-8: If this Non-Recurring (NRE) expenditure, identify it in the checkbox and then define the NRE cost and the number of units for which this NRE cost is applicable.
- Step-9: Repeat steps 3-8 for the "labor" tab and the "Other" tab.
- The DFA-Tool will compute the center of gravity of this imaginary triangle which is the representative result.

4.3.2 Examples

The example depicted in Figure 4-5 identifies a component Upgrade Cost data set of the Payload (PYLD) in a "Detailed" configuration. The Materials, Labor and Other costs are €65K, €75K and €90K respectively, for a total of €230K. The "material" cost is composed of NRE cost of €30K divided into 2 PYLD units plus RE cost of €50K.

The example depicted in Figure 4-6 identifies a component Upgrade Cost data set of the Air Vehicle (AV) in a "Direct" configuration. The estimated upgrade cost is MIN=€300K, ML=400K€ and MAX=430K€. The final value of the upgrade cost is calculated to be €376K.

4.4 Interface Cost computations

The user can use one of three Interface Cost insertion schemes. Accordingly, the component-level Interface Cost is depicted in Figure 4-7 ("Detailed" scheme), Figure 4-8 ("Partial-total" scheme) and Figure 4-9 ("Total" scheme). The user then inserts the relevant information and the DFA-Tool will compute the overall Interface Cost (IC) of the given interface.

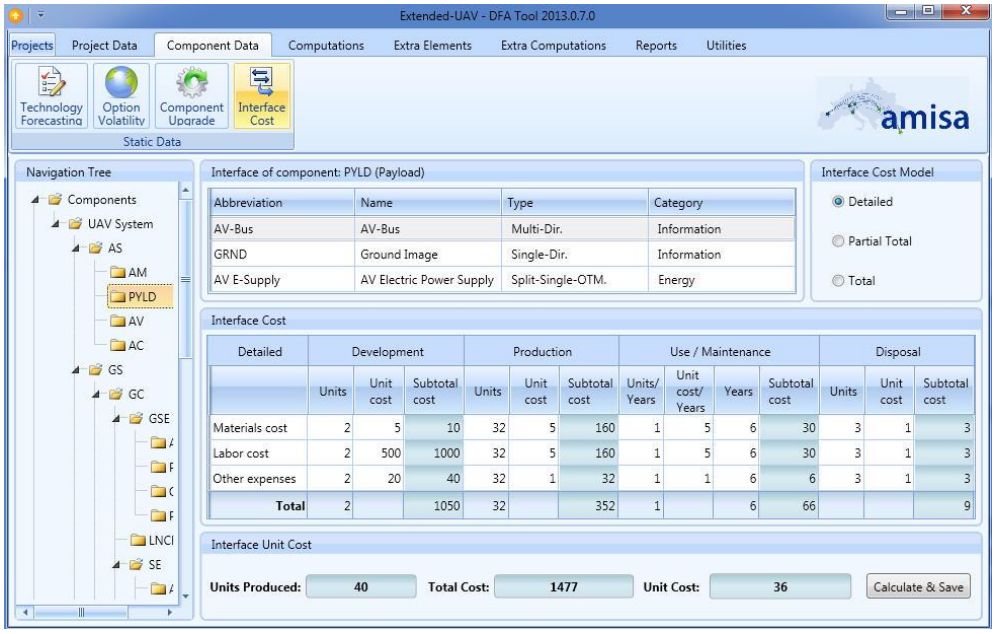


Figure 4-7 – Interface Cost Computations – "Detailed" model

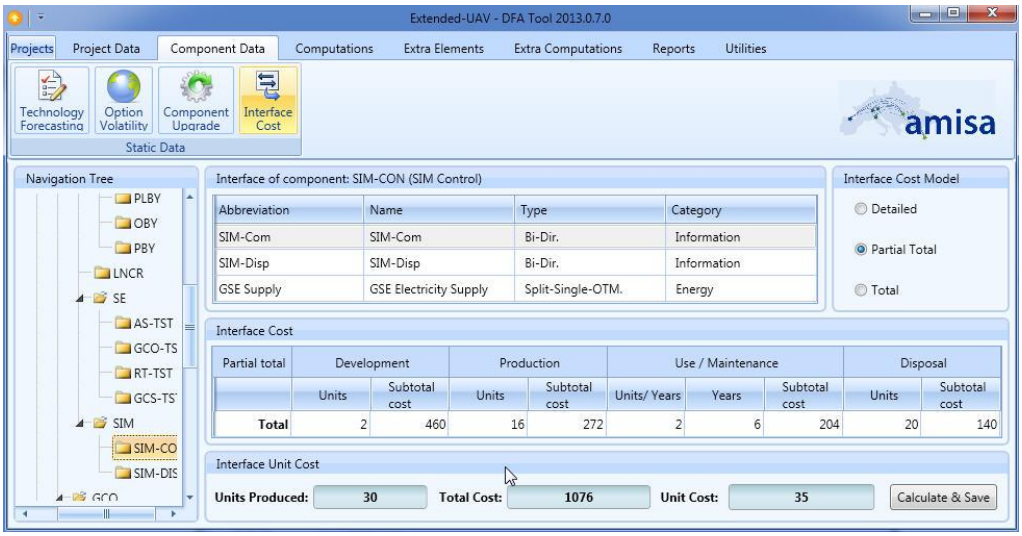


Figure 4-8 - Interface Cost Computations – "Partial-total" model

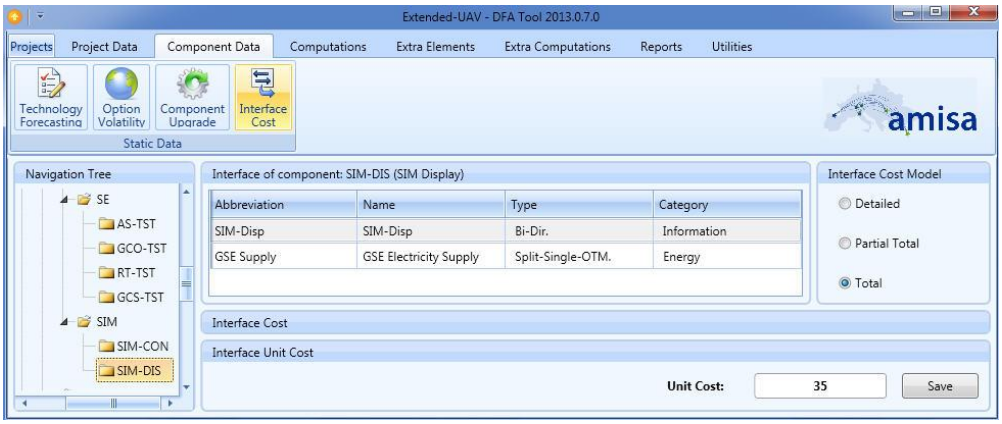


Figure 4-9 - Interface Cost Computations – "Total" model

4.4.1 Procedure

The procedure to Add/Modify/Delete component-level Interface Cost data is carried out following these steps:

- Step-1: Right click on the relevant component in the navigation tree in order to select interface connected to this component.
- Step-2: Right click on the relevant interface in the Interface table in order to select the desired interface.
- Step-3: Right click on the desired model (Detailed, Partial total or Total) and select the desired action (Add, Modify, Delete). The relevant model, depicted in one of the above three figures will appear on the screen.
- Step-4: Assuming the user selects the add Interface Cost data as the action desired. The user should insert the appropriate data and the DFA-Tool will compute the unit cost related to the selected interface.

4.4.2 Examples

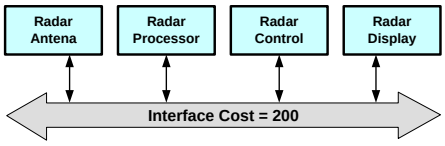
1. In the first example depicted in Figure 4-7, the user selects the *Detailed* insertion scheme. He inserts the number of units to be developed (Units=2) as well as unit costs required for the development phase of the interface (Material cost = €5K, Labor cost = €500K and Other expenses = €20K). Similarly, the user inserts the needed information for the Production, Use/Maintenance and Disposal phases. The overall interface cost of this single unit is €36K
2. In the Second example depicted in Figure 4-8, the user selects the *Partial Total* insertion scheme. He inserts the number of units and the subtotal cost for each phase of the system lifecycle (i.e. Development, Production, Use/Maintenance and Disposal phases). The overall interface cost of this single unit is €35K.
3. In the third example depicted in Figure 4-9, the user selects the *Total* insertion scheme. He only inserts the a single unit interface cost which is, in this example €35K

4.5 Interface cost and DSM

The DFA-Tool will distribute the interface costs associated with each interface under either a manual or automatic mode.

4.5.1 Manual interface cost distribution (not implemented)

In this mode the DFA-Tool will allow users to distribute interface cost within relevant DSM cells manually as they see fit. Figure 4-10 describes an example of placing costs of uneven interface dataflow / costs within the DSM.



	Radar Antena	Radar Processor	Radar Control	Radar Display	Env
Radar Antena		90			
Radar Processor			10	50	
Radar Control	10	20		10	
Radar Display			10		
Env					

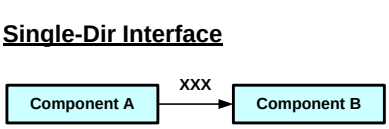
Figure 4-10 – Uneven information flow suggests uneven interface cost distribution

4.5.2 Automatic interface cost distribution (implemented)

In this mode the DFA-Tool will distribute automatically the interface cost over the Design Structure Matrix (DSM) depending on the direction and nature of the interface type. The following paragraphs explain this approach.

4.5.2.1 Single direction interface

Single direction interface means that the interface goes in one direction (i.e. from A to B). The DFA-Tool implements this type of interface by placing the interface cost appropriately in the DSM. The following figure describes this case assuming the total cost of the interface is 60.

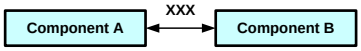


Interface Cost = 60

	A	B	C	Env
A		60		
B				
C				
Env				

4.5.2.2 Bi-direction interface

Bi-direction interface means that the interface goes in two directions (i.e. from A to B and from B to A). The DFA-Tool implements this type of interface by placing half of the interface cost in each of the relevant locations of the DSM. The following figure describes this case assuming the total cost of the interface is 60.

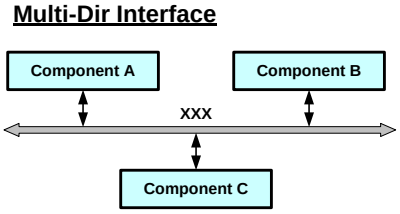


Interface Cost = 60

	A	B	C	Env
A		30		
B	30			
C				
Env				

4.5.2.3 Multi-direction interface (Bus)

Multi-direction interface (Bus) means that the interface goes in two directions within the entire set of the connected elements (e.g. in a set of three connected elements, A, B, C, the interactions are: A=>B, B=>A, A=>C, C=>A, B=>C and C=>B). The DFA-Tool implements this type of interface by placing $1/(2n)$ of the interface cost in each of the relevant locations of the DSM (where n = number of connected elements in the set)[2]. The following figure describes this case assuming the total cost of the interface is 60.



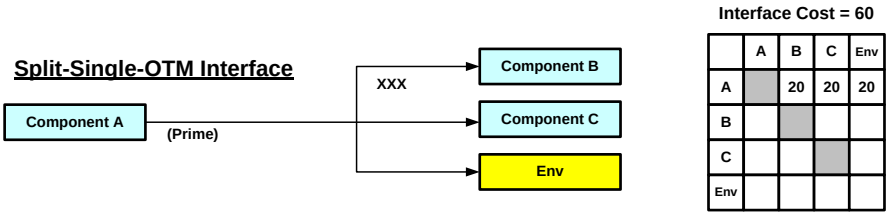
Interface Cost = 60

	A	B	C	Env
A		10	10	
B	10		10	
C	10	10		
Env				

4.5.2.4 Split single One-To-Many direction interface

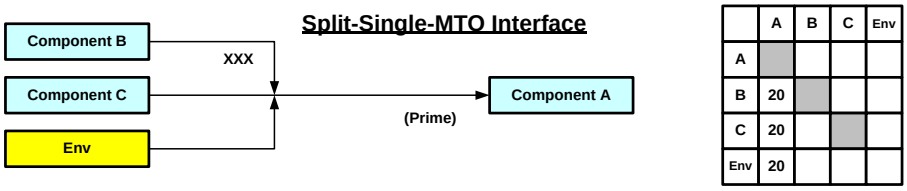
Split single One-To-Many direction interface means that a single interface goes in one direction from one source (Prime) into several destinations (e.g. in a set of four connected elements, A, B, C and Env, the interactions are: A =>B, A=>C and A=>Env). The DFA-Tool implements this type of interface by placing $1/(n-1)$ of the interface cost in each of the relevant locations of the DSM (where n = number of connected elements in the set). The following figure describes this case assuming the total cost of the interface is 60.

[2] Special cost distribution occurs when only two elements are interfaced via a Bus. In such situation: $n = 1/2$.



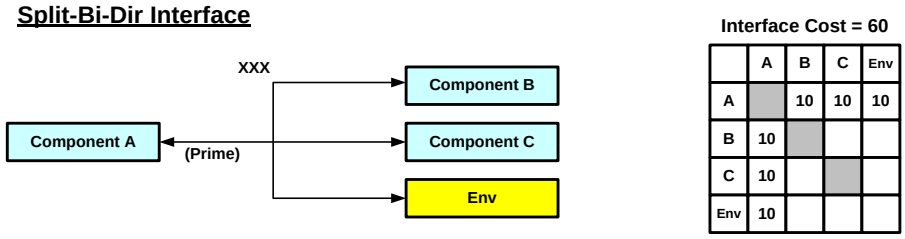
4.5.2.5 *Split single Many-To-One direction interface*

Split single Many-To-One direction interface means that several interfaces go in one direction from several sources into a single (Prime) destination (e.g. in a set of four connected elements, A, B, C and Env, the interactions are: B =>A, C=>A and Env=>A). The DFA-Tool implements this type of interface by placing $1/(n-1)$ of the interface cost in each of the relevant locations of the DSM (where n = number of connected elements in the set). The following figure describes this case assuming the total cost of the interface is 60.



4.5.2.6 *Split Bi Direction interface*

Split Bi Direction interface means that the interface goes in two directions from one source (Prime) into several destinations and back (e.g. in a set of four connected elements, A, B, C and Env, the interactions are: A=>B, B=>A, A=>C, C=>A, A=>Env and Env=>A). The DFA-Tool implements this type of interface by placing $1/(2(n-1))$ of the interface cost in each of the relevant locations of the DSM (where n = number of connected elements in the set). The following figure describes this case assuming the total cost of the interface is 60.



5. Computations

The purpose of this portion of the DFA-Tool is to support the following computation facilities: (1) Architecture, (2) Dynamic structure and (3) Sensitivity analysis (see below).

5.1 Architecture

Deal with the following functionalities: (1) Design Structure Matrix (DSM) generation, (2) Manual system design (3) Constraints definition, (4) Optimize system design and (5) Bottom-up recombination.

5.1.1 Design Structure Matrix (DSM) generation

The DFA-Tool is able to generate five variants of DSMs, depending on the category of interface (Material, Spatial, Energy, Information and a Combined interfaces). Figure 5-1 depicts the Man-Machine interaction GUI. Figure 5-2 depicts a generated Information-DSM of the target system. This includes identification of all the leaf-components, computation of their option values to be placed along the DSM diagonal. In addition, all Information-category interfaces associated with the leaf-components are identified and their costs are placed appropriately in the DSM. The reader should note that the DFA-Tool will place a "--" symbol in cells where certain data, needed for the calculation, is missing.

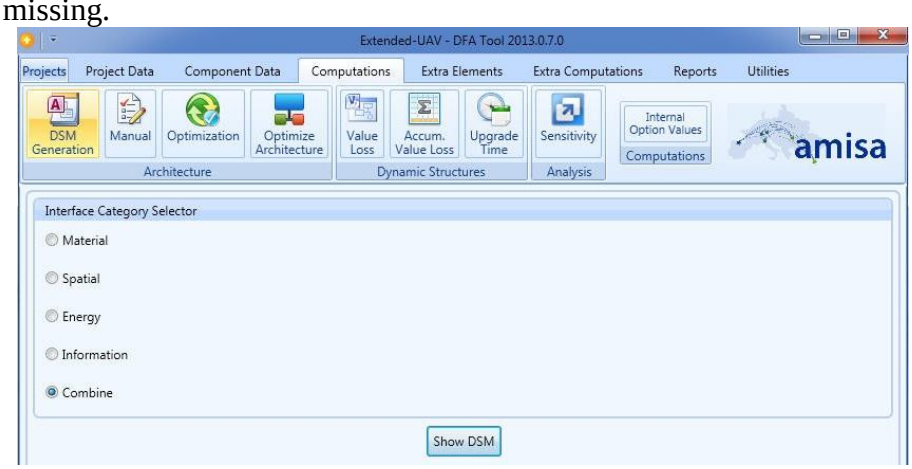


Figure 5-1 – DSM generating GUI

Extended-UAV, DSM Generation

	AM	PYLD	AV	AC	ABY	PLBY	OBY	PBY	LNCR	AS-TST	GCO-TST	RT-TST	GCS-TST	SIM-CON	SIM-DIS	GCO-TRNS	GCO-REC	GCO-CON	RT-REC	RT-DIS	RT-CON	RT_Vehicle	GEN	Env
AM	63.2	4.5	4.5	4.5						19														
PYLD	4.5	176.5	4.5	4.5																				
AV	14.5	14.5	752.5	14.5																				
AC	4.5	4.5	4.5	128.7													67.5		67.5					39
ABY					137.4	8.2	8.2	8.2																33
PLBY					8.2	118.2	8.2	8.2																
OBY					8.2	8.2	99.4	8.2																
PBY					8.2	8.2	8.2	80.4	42.5				18.5	17.5				20						
LNCR								42.5	4.8															
AS-TST	19									18.7	8.8	8.8	8.8											
GCO-TST										8.8	18.7	8.8	8.8					18.5						
RT-TST										8.8	8.8	18.7	8.8								18.5			
GCS-TST								18.5		8.8	8.8	8.8	18.7											
SIM-CON								17.5						3.1	17.5									
SIM-DIS														17.5	5									
GCO-TRNS				135												9.1		17.5						
GCO-REC																	9.1	18						
GCO-CON								20			18.5					17.5	18	6.4						
RT-REC																			38.2	11.2	11.2			
RT-DIS																			11.2	21.6	11.2			
RT-CON												18.5							11.2	11.2	39.4			
RT_Vehicle																			16.7	16.7	16.7	2		
GEN					5	5	5	5	5	5	5	5	5	5	5	5	5	5					6.3	
Env		14	60	48	33																	15	45	

Figure 5-2 – Raw DSM Combined example

Users may generate raw DSM based on externally generated Option Values (OVs) (also, see section 9.4) by clicking the Internal/External Option Values button (see Figure 5-3 and Figure 5-4).

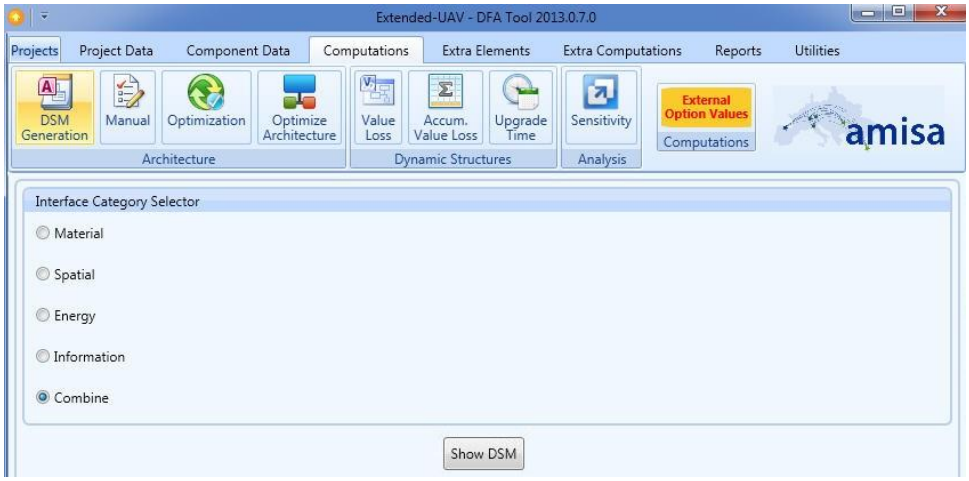
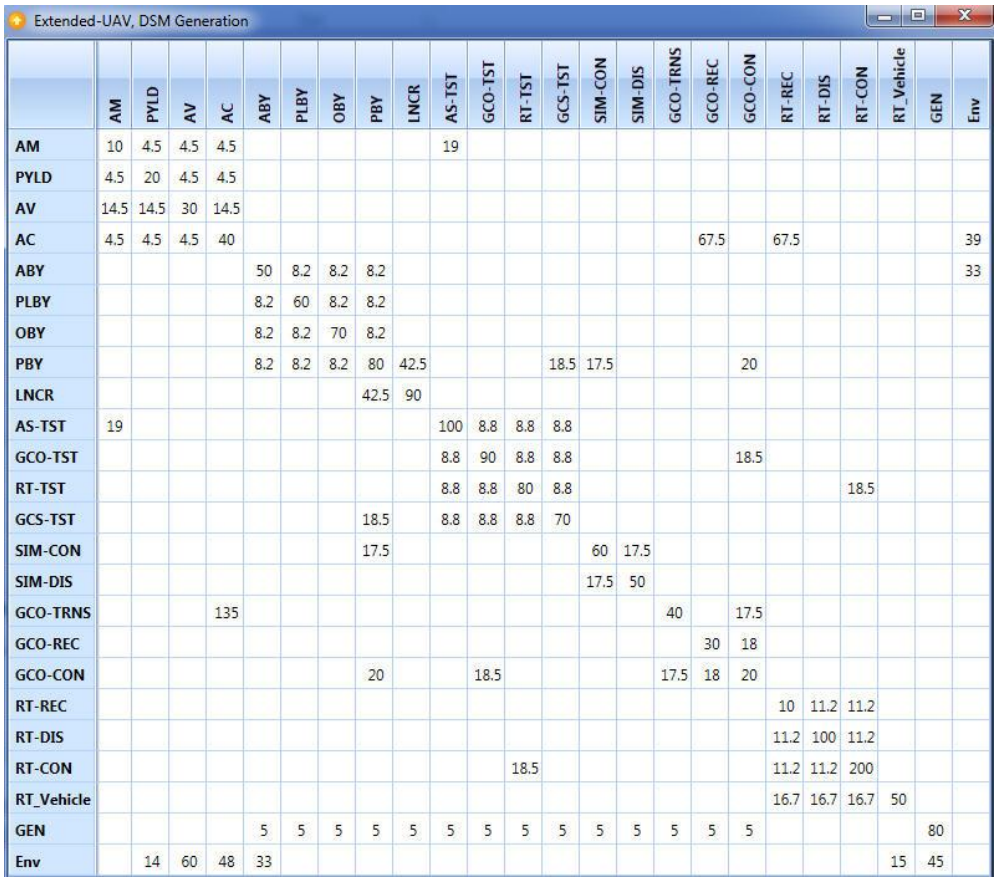


Figure 5-3 - DSM generating GUI for external OVs



	AM	PYLD	AV	AC	ABY	PLBY	OBY	PBY	LNCR	AS-TST	GCO-TST	RT-TST	GCS-TST	SIM-CON	SIM-DIS	GCO-TRNS	GCO-REC	GCO-CON	RT-REC	RT-DIS	RT-CON	RT_Vehicle	GEN	Env
AM	10	4.5	4.5	4.5						19														
PYLD	4.5	20	4.5	4.5																				
AV	14.5	14.5	30	14.5																				
AC	4.5	4.5	4.5	40													67.5		67.5					39
ABY					50	8.2	8.2	8.2																33
PLBY					8.2	60	8.2	8.2																
OBY					8.2	8.2	70	8.2																
PBY					8.2	8.2	8.2	80	42.5				18.5	17.5				20						
LNCR								42.5	90															
AS-TST	19									100	8.8	8.8	8.8											
GCO-TST										8.8	90	8.8	8.8					18.5						
RT-TST										8.8	8.8	80	8.8								18.5			
GCS-TST								18.5		8.8	8.8	8.8	70											
SIM-CON								17.5						60	17.5									
SIM-DIS														17.5	50									
GCO-TRNS				135												40		17.5						
GCO-REC																	30	18						
GCO-CON								20			18.5					17.5	18	20						
RT-REC																			10	11.2	11.2			
RT-DIS																			11.2	100	11.2			
RT-CON												18.5							11.2	11.2	200			
RT_Vehicle																			16.7	16.7	16.7	50		
GEN					5	5	5	5	5	5	5	5	5	5	5	5	5	5					80	
Env		14	60	48	33																	15	45	

Figure 5-4 - Raw Combined DSM example for external OVs

5.1.1.1 Procedure

Clicking on the DSM generation icon will display the DSM generating GUI window.

- Step-1: The user may choose one of five interface categories (Material, Spatial, Energy, Information and a Combined interfaces) in order to generate an appropriate DSM
- Step-2: The user may click the Show DSM button in order to create the desired matrix. Missing information in the database (if exists) is depicted by a sequence of two dashes (--).

5.1.1.2 Example

The Option Price and Interface cost associated with each leaf-component is depicted in the DSM matrix.

5.1.2 Manual system design

The DFA-Tool is able to generate manual system designs. That is, the user can manually define the architecture of the target system in order to compute the system overall Architecture Adaptability Value. As mentioned before, the system can produce five variants of DSMs, dependent on the category of interface (Material, Spatial, Energy, Information and a Combined interfaces). Figure 5-5 depicts this Manual combined DSM generation GUI. Figure 5-6 depicts a Combine-DSM of the target system. The DFA-Tool will place a "--" symbol in cells where certain data, needed for the calculation, is missing.

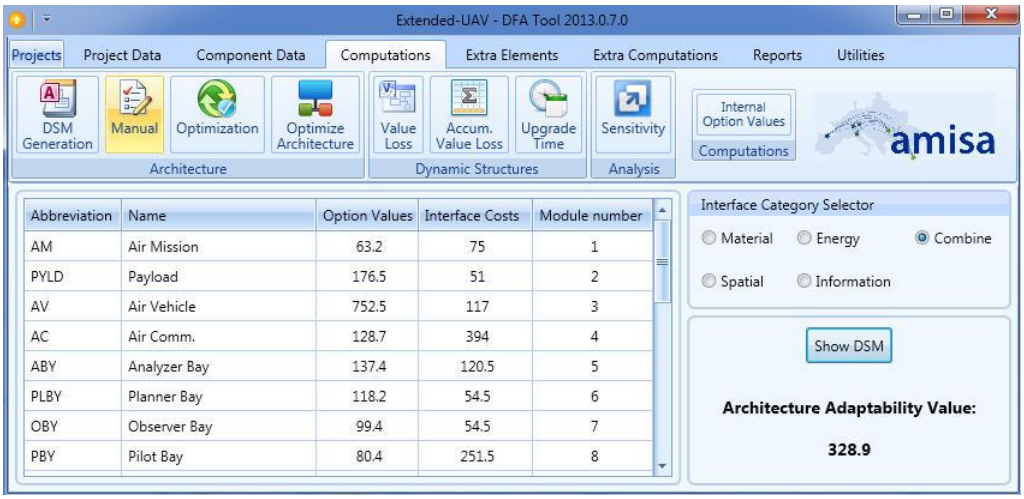


Figure 5-5 – Manual system design GUI

AAV: 328.9, Extended-UAV, Manual DSM

	AM	PYLD	AV	AC	ABY	PLBY	OBY	PBY	LNCR	AS-TST	GCO-TST	RT-TST	GCS-TST	SIM-CON	SIM-DIS	GCO-TRNS	GCO-REC	GCO-CON	RT-REC	RT-DIS	RT-CON	RT_Vehicle	GEN	Env
AM	63.2	4.5	4.5	4.5						19														
PYLD	4.5	176.5	4.5	4.5																				
AV	14.5	14.5	752.5	14.5																				
AC	4.5	4.5	4.5	128.7													67.5		67.5					39
ABY					137.4	8.2	8.2	8.2																33
PLBY					8.2	118.2	8.2	8.2																
OBY					8.2	8.2	99.4	8.2																
PBY					8.2	8.2	8.2	80.4	42.5				18.5	17.5				20						
LNCR								42.5	4.8															
AS-TST	19									18.7	8.8	8.8	8.8											
GCO-TST										8.8	18.7	8.8	8.8					18.5						
RT-TST										8.8	8.8	18.7	8.8								18.5			
GCS-TST								18.5		8.8	8.8	8.8	18.7											
SIM-CON								17.5						3.1	17.5									
SIM-DIS														17.5	5									
GCO-TRNS				135												9.1		17.5						
GCO-REC																	9.1	18						
GCO-CON								20			18.5					17.5	18	6.4						
RT-REC																			38.2	11.2	11.2			
RT-DIS																			11.2	21.6	11.2			
RT-CON												18.5							11.2	11.2	39.4			
RT_Vehicle																			16.7	16.7	16.7	2		
GEN					5	5	5	5	5	5	5	5	5	5	5	5	5	5					6.3	
Env		14	60	48	33																	15	45	

Figure 5-6 – DSM representing manual system design

Users may generate manual DSM based on externally generated Option Values (OVs) (also, see section 9.4) by clicking the Internal/External Option Values button (see Figure 5-7 and Figure 5-8).

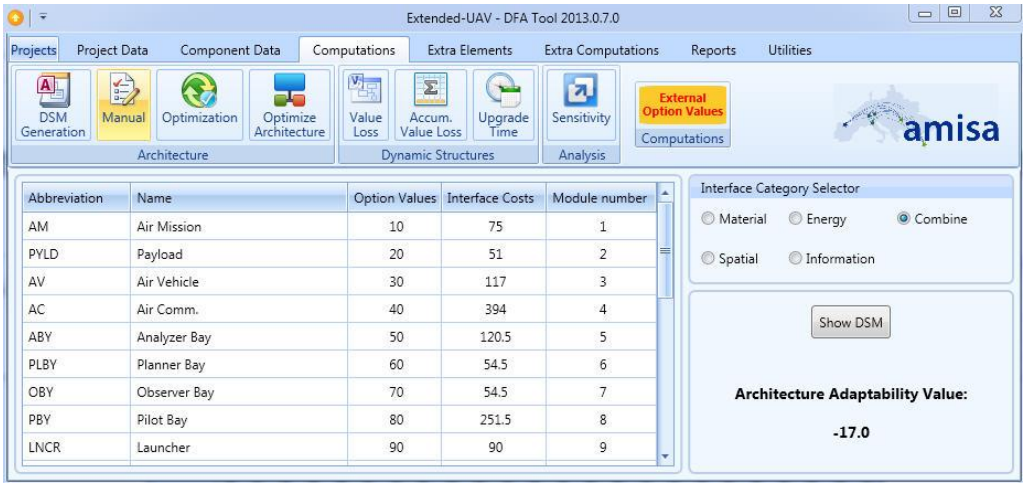
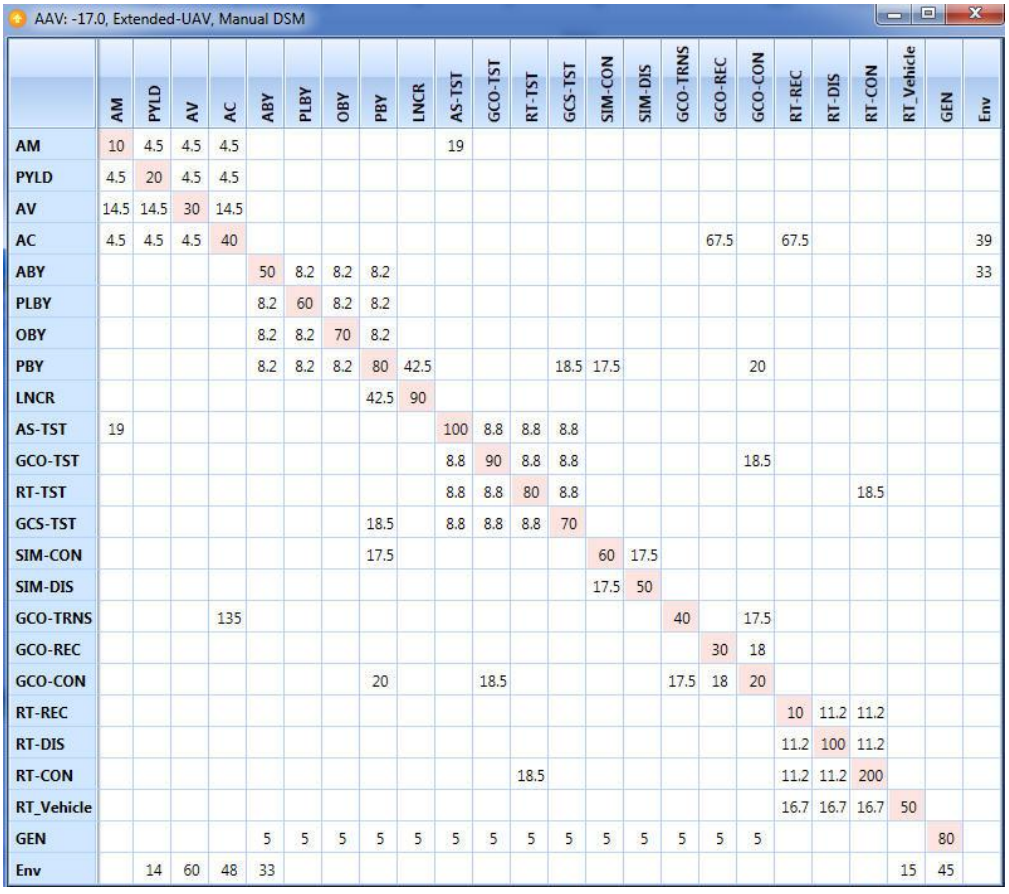


Figure 5-7 - Manual system design GUI based on External OVs



	AM	PYLD	AV	AC	ABY	PLBY	OBY	PBY	LNCR	AS-TST	GCO-TST	RT-TST	GCS-TST	SIM-CON	SIM-DIS	GCO-TRNS	GCO-REC	GCO-CON	RT-REC	RT-DIS	RT-CON	RT_Vehicle	GEN	Env
AM	10	4.5	4.5	4.5						19														
PYLD	4.5	20	4.5	4.5																				
AV	14.5	14.5	30	14.5																				
AC	4.5	4.5	4.5	40													67.5		67.5					39
ABY					50	8.2	8.2	8.2																33
PLBY					8.2	60	8.2	8.2																
OBY					8.2	8.2	70	8.2																
PBY					8.2	8.2	8.2	80	42.5				18.5	17.5				20						
LNCR								42.5	90															
AS-TST	19									100	8.8	8.8	8.8											
GCO-TST										8.8	90	8.8	8.8					18.5						
RT-TST										8.8	8.8	80	8.8								18.5			
GCS-TST								18.5		8.8	8.8	8.8	70											
SIM-CON								17.5						60	17.5									
SIM-DIS														17.5	50									
GCO-TRNS				135												40		17.5						
GCO-REC																	30	18						
GCO-CON								20			18.5					17.5	18	20						
RT-REC																			10	11.2	11.2			
RT-DIS																			11.2	100	11.2			
RT-CON												18.5							11.2	11.2	200			
RT_Vehicle																			16.7	16.7	16.7	50		
GEN					5	5	5	5	5	5	5	5	5	5	5	5	5	5					80	
Env		14	60	48	33																	15	45	

Figure 5-8 - DSM representing manual system design based on External OVs

5.1.2.1 Procedure

The procedure to manually create a system design (i.e. assign individual leaf-components to individual modules) involves the following:

- Step-1: On selecting "Computations" and clicking the Manual icon, the DFA-Tool will generate a Leaf-components table, identifying the abbreviated and the full names of all the defined leaf-components together with the components' Option Price (OP) and Interface Costs (IC). The DFA-Tool will initially assign each component to a unique module.
- Step-2: The user may choose one of five interface categories (Material, Spatial, Energy, Information and a Combined interfaces) to generate appropriate DSM.
- Step-3: The user will be able to click on a module numbers of any leaf-component and assign a desired module number to the given leaf-component.
- Step-4: The user will be able to click on the "Show DSM" button. This will cause the following:
  - The tool will generate a Design Structure Matrix (DSM) reflecting the user manual design.
  - The tool will compute the target system Architecture Adaptability Value reflecting the user manual design of the target system.

5.1.2.2 Example

In the example depicted in Figure 5-5 and Figure 5-6 the user defined the DSM category as "Combine", creates a manual architecture of the system as defined by the user and computes the Architecture Adaptability Value, yielding €328.9K.

5.1.3 Genetic Algorithm optimization

5.1.3.1 GA methodology

Evolutionary algorithms are powerful techniques used to find solutions to many real-world search and optimization problems. Genetic Algorithms (GA) are numerical analysis techniques that seem particularly suitable for solving optimization problems in a non-continues search space.

Biological background. All living organisms consist of cells in which, there are the same set of chromosomes. Chromosomes serve as a pattern for the construction of the entire organism. A chromosome consists of genes, each encodes a particular trait or capability of the organism for example, the ability to run fast. During reproduction, a recombination (or crossover) first occurs. Genes from parents combine to form a completely new chromosome. The newly created offspring may then be mutated. Mutation means that the elements of DNA are slightly changed. These changes are mainly caused by errors in inheriting genes from one's parents. The fitness of an organism is measured by the success of the organism to survive.

Search space. When we are solving a problem with multiple solutions, we usually look for a solution, which will be better than all the others. The space of all feasible solutions e.g. the set of all solutions is called the search space. Each element in the search space represents a single possible solution. Each possible solution can be assessed by its survival fitness. By using GA we are looking for the best solution from a number of other possible solutions - represented by one point in the search space. Looking for a solution is equal to looking for some extreme value (minimum or maximum) in the search space. At times, the search space can be well defined, but usually we only know a few points in the search space. In the process of using GA, the process of finding solutions generates other possible solutions as evolution proceeds.

The GA algorithm. Genetic algorithms use an evolutionary process beginning with a set of initial solutions (represented by chromosomes) called population. This population is then used to form a new population on a cyclical basis. The strategy is based the anticipation that the new population will be better than the old one. New solutions (offspring) are selected according to their suitability - the more suitable they are the more chance they have to reproduce. This is repeated until some condition, for example improvement of the best solution, is satisfied. As can be seen, the outline of the Basic GA is very general. Many parameters and settings can be implemented differently in various problems. The basic genetic algorithm is outlined in Table 5-1.

Table 5-1 - Basic genetic algorithm

Step	Stage	Actions
1.	Start	Generate random population of n chromosomes (suitable solutions for the problem).
2.	Suitability	Evaluate the suitability f(x) of each chromosome x in the population.
3.	New population	Create a new population by repeating the following steps until the new population is complete
4.	Elitism	Select one or more of the most suitable parent chromosomes and transfer them to the new population
5.	Selection	Select two parent chromosomes from a population according to their suitability (the more suitable they are, the higher chance they have to be selected)
6.	Crossover	With a crossover probability, selected set of parents form new offspring. If no crossover was performed, the offspring will be the exact copy of parents
7.	Mutation	With a mutation probability, mutate new offspring at each locus (the position in the chromosome).
8.	Replace	Place the new offspring in the new population and replace / remove part or all the old population. The current population is used to continue the algorithm.
9.	Test	If the end condition is satisfied, stop, and return the best solution in the current population
10.	Loop	Proceed to step 2

5.1.3.2 GA operators

Elitism. When creating a new population by crossover and mutation, we have a certain chance, that we will lose the best chromosome. Therefore, the purpose of elitism is to ensure that the best chromosomes are always transmitted into the new generation. Elitism invariably increases the performance of GA, because it prevents a loss of the one or more best-found solution.

Crossover. Crossovers operate on selected genes from the parents' chromosomes and create new offspring. The simplest way to do this is to choose some crossover point at random, and then to copy everything before this point from the first parent, and then copy everything after the crossover point from the other parent.

Mutation. Mutation is intended to prevent the algorithm from sinking into a local optimum. In other words, mutation introduces randomness and divergence into the population. Most often mutation will create unattractive solutions. But every now and then it will lead to a breakthrough solution. Mutation randomly changes an offspring which has resulted from a crossover operation

Iterations. There are several ways to affect the stopping criteria of GA. In this case the stopping criterion is the number of optimization cycles to be carried out by the computer.

5.1.4 Optimize system design

The DFA-Tool generates an optimized system design. That is, the user can define the parameters of a Genetic Algorithm and then run the optimizer seeking to identify the maximum Architecture Adaptability Value. If exclusion rules are defined in the project, the optimizer optimizes each exclusion sets serially. This technique reduces the overall number of optimization permutations significantly. As mentioned before, the system can produce five variants of DSMs, dependent on the category of interface (Material, Spatial, Energy, Information and a Combined interfaces). Figure 5-9 depicts this GUI.

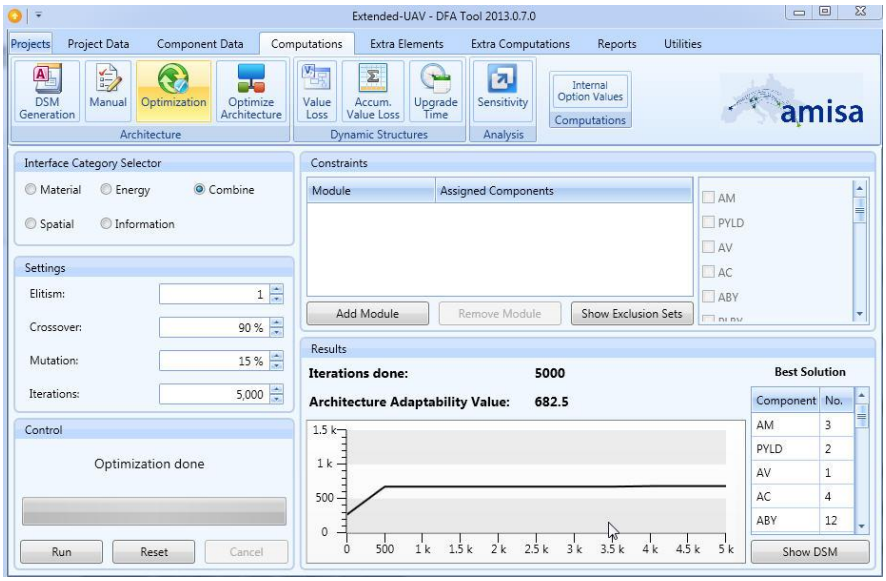
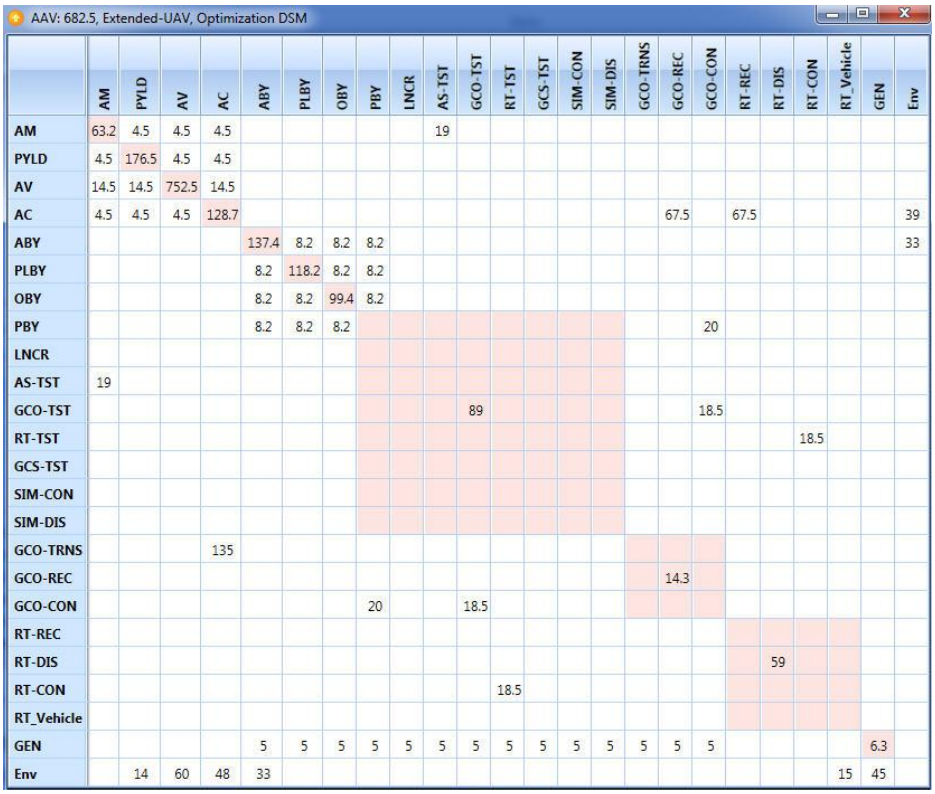


Figure 5-9 – Optimization system design GUI

Figure 5-10 depicts an Information-DSM of the target system. The DFA-Tool will place a "--" symbols in cells where certain data, needed for the calculation, is missing.



	AM	PYLD	AV	AC	ABY	PLBY	OBY	PBY	LNCR	AS-TST	GCO-TST	RT-TST	GCS-TST	SIM-CON	SIM-DIS	GCO-TRNS	GCO-REC	GCO-CON	RT-REC	RT-DIS	RT-CON	RT_Vehicle	GEN	Env
AM	63.2	4.5	4.5	4.5						19														
PYLD	4.5	176.5	4.5	4.5																				
AV	14.5	14.5	752.5	14.5																				
AC	4.5	4.5	4.5	128.7													67.5		67.5					39
ABY					137.4	8.2	8.2	8.2																33
PLBY					8.2	118.2	8.2	8.2																
OBY					8.2	8.2	99.4	8.2																
PBY					8.2	8.2	8.2											20						
LNCR																								
AS-TST	19																							
GCO-TST											89							18.5						
RT-TST																					18.5			
GCS-TST																								
SIM-CON																								
SIM-DIS																								
GCO-TRNS				135																				
GCO-REC																	14.3							
GCO-CON								20			18.5													
RT-REC																								
RT-DIS																				59				
RT-CON												18.5												
RT_Vehicle																								
GEN					5	5	5	5	5	5	5	5	5	5	5	5	5	5					6.3	
Env		14	60	48	33																	15	45	

Figure 5-10 – Combined DSM representing optimized system design

5.1.4.1 Procedure

The procedure to create an optimal system design involves the following:

- Step-1: On selecting "Computations" and clicking the Optimization icon, the DFA-Tool will optimization system design GUI.
- Step-2: The user may choose one of five interface categories (Material, Spatial, Energy, Information and a Combined interfaces) to generate appropriate DSM.
- Step-3: The user will be able to modify the Genetic Algorithm parameters to suit his needs (see section 5.1.3.2) then he will click the Run button to initiate the optimization process. At the end of the optimization process, the tool will compute and show the optimized system Architecture Adaptability Value.
- Step-4: The user will be able to click on the "Show DSM" button and the tool will generate the optimized Design Structure Matrix (DSM).

5.1.4.2 Example

In the example depicted in Figure 5-9 and Figure 5-10 the user defined the DSM category as "Information", runs the optimization process and computes the Architecture Adaptability Value, yielding €682.5K. In addition, it creates an optimal architecture of the system.

5.1.4.3 Show Exclusion Sets

The user may view the DSM of these exclusion zones (Figure 5-11) by clicking on the "Show Exclusion Sets" button.

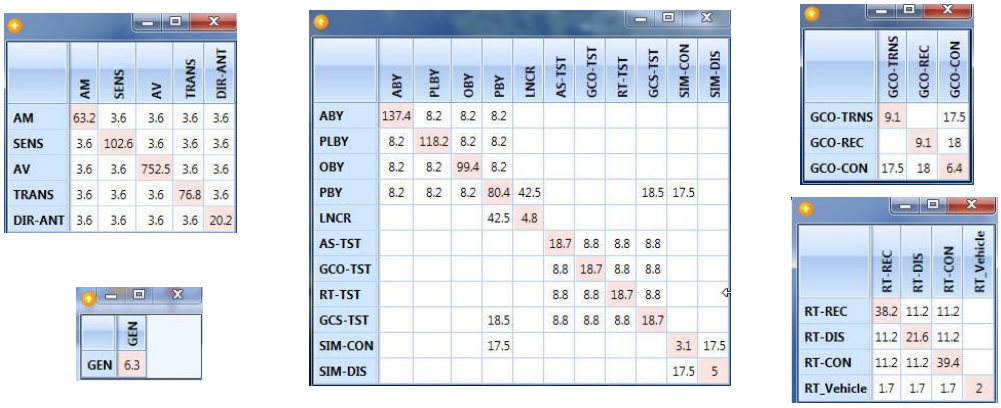

AM SENS AV TRANS DIR-ANT
AM 63.2 3.6 3.6 3.6 3.6
SENS 3.6 102.6 3.6 3.6 3.6
AV 3.6 3.6 752.5 3.6 3.6
TRANS 3.6 3.6 3.6 76.8 3.6
DIR-ANT 3.6 3.6 3.6 3.6 20.2
GEN
GEN 6.3
ABY PLBY OBY PBY LNCR AS-TST GCO-TST RT-TST GCS-TST SIM-CON SIM-DIS
ABY 137.4 8.2 8.2 8.2
PLBY 8.2 118.2 8.2 8.2
OBY 8.2 8.2 99.4 8.2
PBY 8.2 8.2 8.2 80.4 42.5 18.5 17.5
LNCR 42.5 4.8
AS-TST 18.7 8.8 8.8 8.8
GCO-TST 8.8 18.7 8.8 8.8
RT-TST 8.8 8.8 18.7 8.8
GCS-TST 18.5 8.8 8.8 8.8 18.7
SIM-CON 17.5 3.1 17.5
SIM-DIS 17.5 5
GCO-TRNS GCO-REC GCO-CON
GCO-TRNS 9.1 17.5
GCO-REC 9.1 18
GCO-CON 17.5 18 6.4
RT-REC RT-DIS RT-CON RT_Vehicle
RT-REC 38.2 11.2 11.2
RT-DIS 11.2 21.6 11.2
RT-CON 11.2 11.2 39.4
RT_Vehicle 1.7 1.7 1.7 2

Figure 5-11 – DSMs representing Exclusion Sets – UAV example

5.1.4.4 Using external Option Values

Users may generate optimized DSM based on externally generated Option Values (OVs) by clicking the Internal/External Option Values button. The procedure is similar and the optimized DSM value for this external data is 108 (see Figure 5-12 and Figure 5-13).

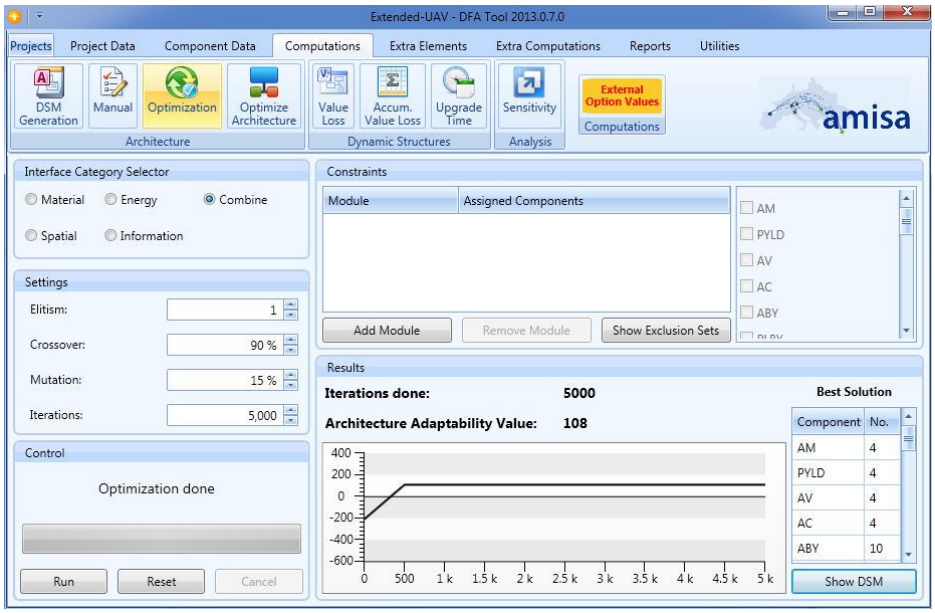
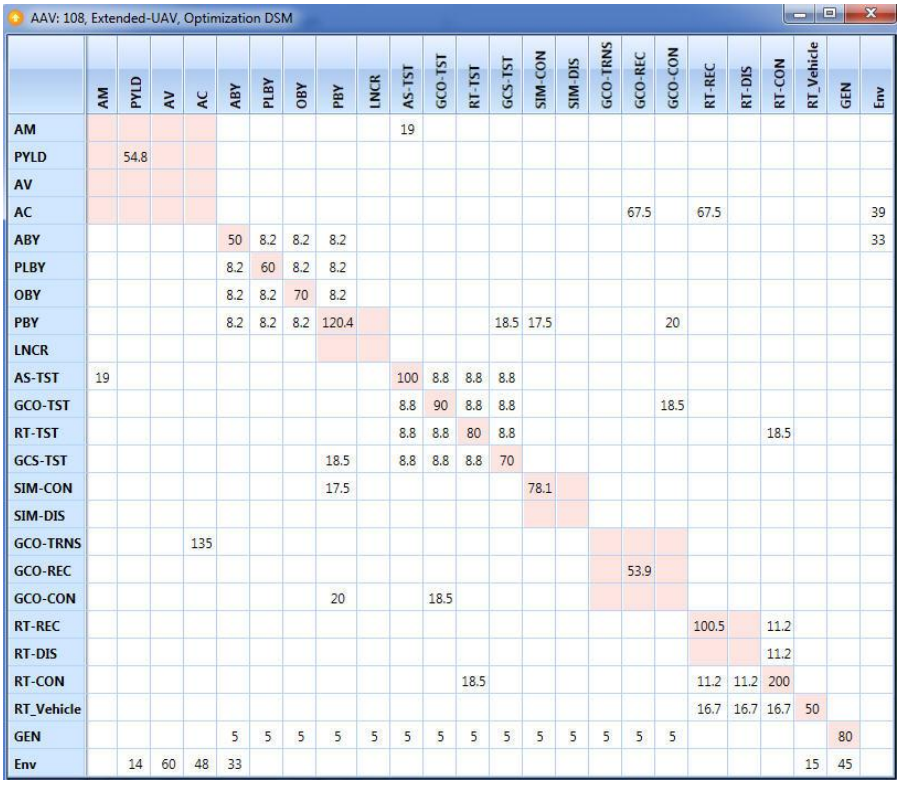


Figure 5-12 - Optimization system design GUI based on External OVs



	AM	PYLD	AV	AC	ABY	PLBY	OBY	PBY	LNCR	AS-TST	GCO-TST	RT-TST	GCS-TST	SIM-CON	SIM-DIS	GCO-TRNS	GCO-REC	GCO-CON	RT-REC	RT-DIS	RT-CON	RT_Vehicle	GEN	Env
AM										19														
PYLD		54.8																						
AV																								
AC																	67.5		67.5					39
ABY					50	8.2	8.2	8.2																33
PLBY					8.2	60	8.2	8.2																
OBY					8.2	8.2	70	8.2																
PBY					8.2	8.2	8.2	120.4					18.5	17.5				20						
LNCR																								
AS-TST	19									100	8.8	8.8	8.8											
GCO-TST										8.8	90	8.8	8.8					18.5						
RT-TST										8.8	8.8	80	8.8								18.5			
GCS-TST								18.5		8.8	8.8	8.8	70											
SIM-CON								17.5						78.1										
SIM-DIS																								
GCO-TRNS				135																				
GCO-REC																	53.9							
GCO-CON								20			18.5													
RT-REC																			100.5		11.2			
RT-DIS																					11.2			
RT-CON												18.5							11.2	11.2	200			
RT_Vehicle																			16.7	16.7	16.7	50		
GEN					5	5	5	5	5	5	5	5	5	5	5	5	5	5					80	
Env		14	60	48	33																	15	45	

Figure 5-13 - DSM representing optimized system design based on External OVs

5.1.5 Constraints definition

This function allows users to specify optimization constraints. Under such constraints, specified components will either: (1) will not be allowed to be combined with other components or (2) be forced to be combined with other components. Figure 5-14 depicts an optimization system design GUI with constraints.

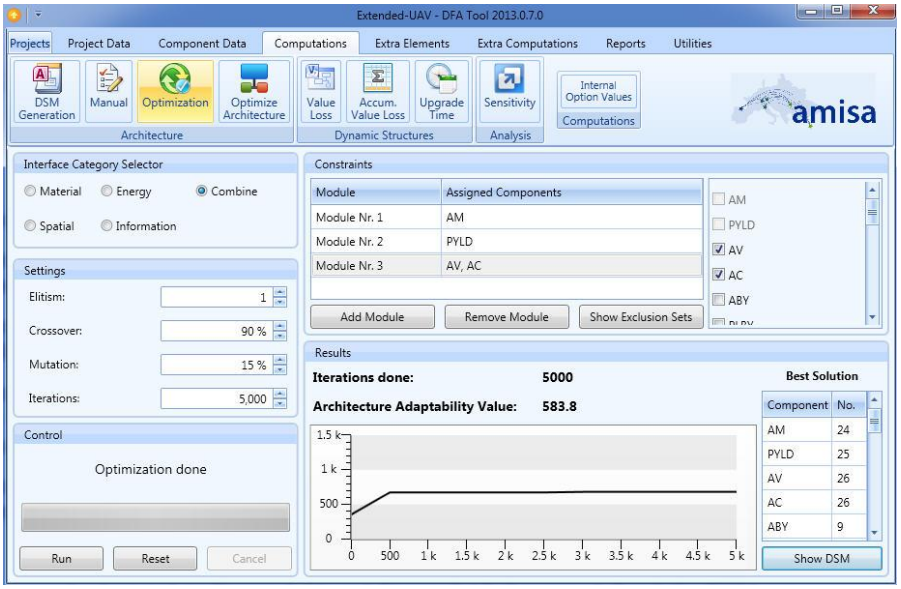
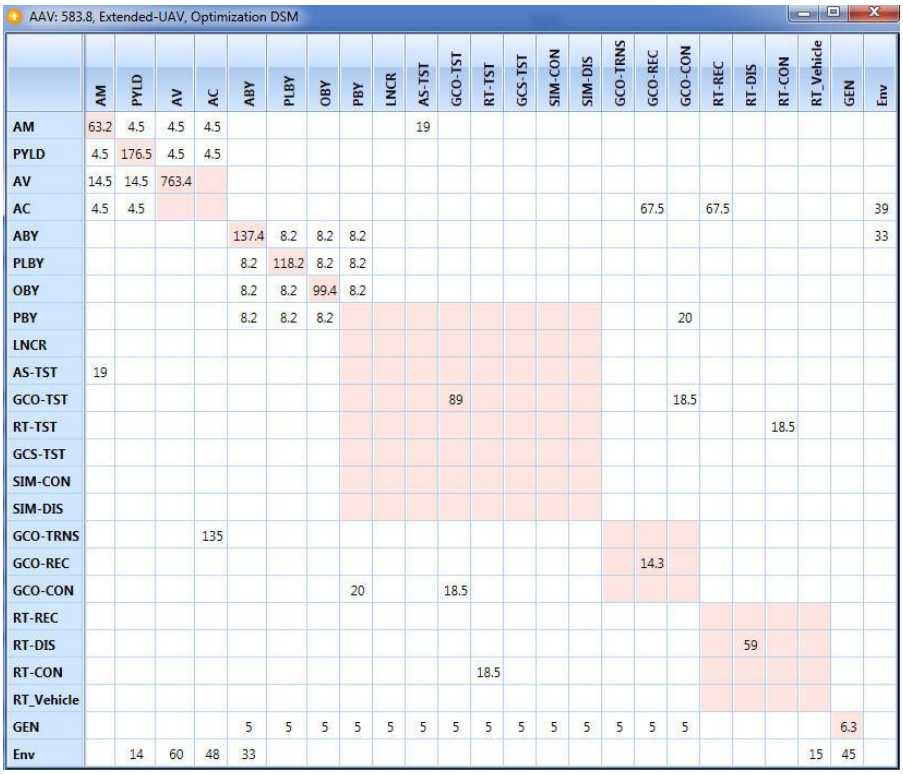


Figure 5-14 – Optimization system design GUI with constraints

In this example The AM (Air Mission) component must be constrained into an individual module and similarly the PYLD (Payload). In addition, the AV (Air Vehicle) and the AC (Air Communication) must both reside in a single module, separated from all other modules. As a result of these constrains the Architecture Adaptability value is €583.8K. The constrained DSM is depicted in Figure 5-15.



	AM	PYLD	AV	AC	ABY	PLBY	OBY	PBY	LNCR	AS-TST	GCO-TST	RT-TST	GCS-TST	SIM-CON	SIM-DIS	GCO-TRNS	GCO-REC	GCO-CON	RT-REC	RT-DIS	RT-CON	RT_Vehicle	GEN	Env
AM	63.2	4.5	4.5	4.5						19														
PYLD	4.5	176.5	4.5	4.5																				
AV	14.5	14.5	763.4																					
AC	4.5	4.5															67.5		67.5					39
ABY					137.4	8.2	8.2	8.2																33
PLBY					8.2	118.2	8.2	8.2																
OBY					8.2	8.2	99.4	8.2																
PBY					8.2	8.2	8.2											20						
LNCR																								
AS-TST	19																							
GCO-TST											89							18.5						
RT-TST																					18.5			
GCS-TST																								
SIM-CON																								
SIM-DIS																								
GCO-TRNS				135																				
GCO-REC																	14.3							
GCO-CON								20			18.5													
RT-REC																								
RT-DIS																				59				
RT-CON												18.5												
RT_Vehicle																								
GEN					5	5	5	5	5	5	5	5	5	5	5	5	5	5					6.3	
Env		14	60	48	33																	15	45	

Figure 5-15 – DSM representing constrained optimized system design

5.1.6 Optimize architecture

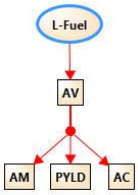
The user can generate a graphical chart of the optimized architecture.

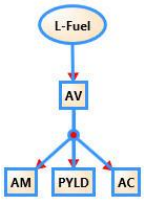
5.1.6.1 Procedure

The procedure to generate graphical charts of optimized architectures is done following these steps:

- Step-1: Select the desired interface category. If the system is complex and contains multi-interface types, the users should generate architecture charts for each type of interface.
- Step-2: If an optimized architecture chart is saved from a previous session then the user can show it by clicking the "Show" button. Note that saved architecture charts may not be valid if relevant database parameters have been modified.
- Step-3: If the user had performed optimization function prior to selecting the "Optimize architecture" tab, then the DFA-Tool will maintain the optimization data and a green indicator on the "Optimize" button will appear. In this case, no further optimization activities are necessary.

- Step-4: Otherwise, click the "Optimize" button and wait for the optimization process to complete (i.e. the green light on the "Optimize" button turns on).
- Step-5: Click on the "Build" button. The raw optimized architecture will be displayed (Often a maximal window is preferable). The detail of each architecture chart is depicted in the blue strip just above the chart.
- Step-6: The user can edit the architecture chart by identifying and moving individual or groups of symbols of components, environments or splitting points of interfaces.





- Step-7: The user can "Save" the edited chart and later "Show" a saved architecture chart by clicking the relevant buttons.
- Step-8: Also the user can change the "Scale" of the image using the slide at the bottom-left.
- Step-9: The user can select an object (i.e. Components, Environment or Interface) and click on the "Parameter" tab. A window will slide open revealing the parameters associated with the selected object.

5.1.6.2 Example

- Figure 5-16 depicts an optimized raw "Combine" architecture of the UAV system (with open parameters window).

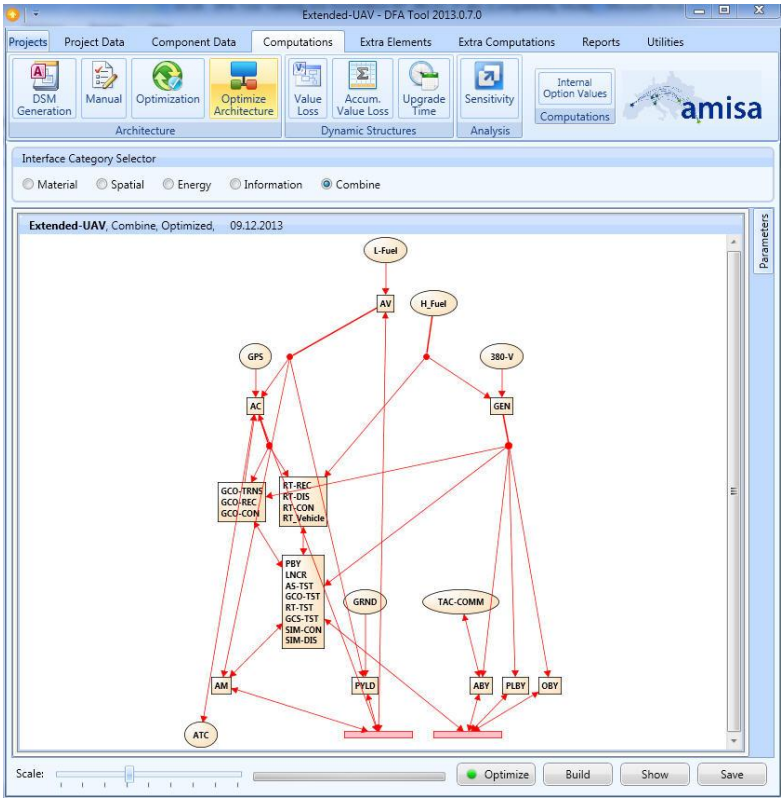


Figure 5-16 - Optimized raw "Combine" architecture – Extended UAV system

- Figure 5-17 depicts the edited optimized "Combine" architecture of the UAV system. In this figure the parameter window is open depicting the selected three components and their parameters.

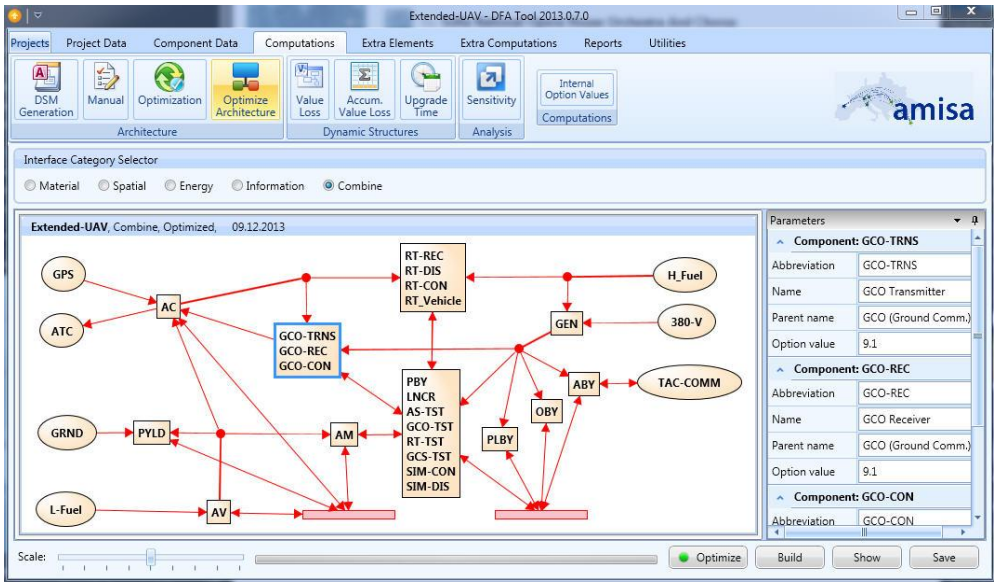


Figure 5-17 – Optimized edited "Combine" architecture – Extended UAV system

5.2 Dynamic structure

The Dynamic Structure computations include (1) Value loss, (2) Accumulated value loss and Upgrade time.

5.2.1 Value loss

Figure 5-18 and Figure 5-19 depict, in graphical form and in tabulated form: (1) The increasing Value Desired (VD) by stakeholders and (2) The decreasing System Value (SV). The difference between VD and SV at any given time is the instantaneous Value Loss (VL) for that time. This Value loss may be expressed by the following equation:

$$VL(t) = VD(t) - SV(t)$$

For example, according to the following two figures, at the end of the 10^{th} year (1) the Value Desired is expected to reach VD=€178,165K, (2) the System Value is expected to be SV=€78,760K and therefore, the Value Loss at that time is expected to be VL=€99,405K.

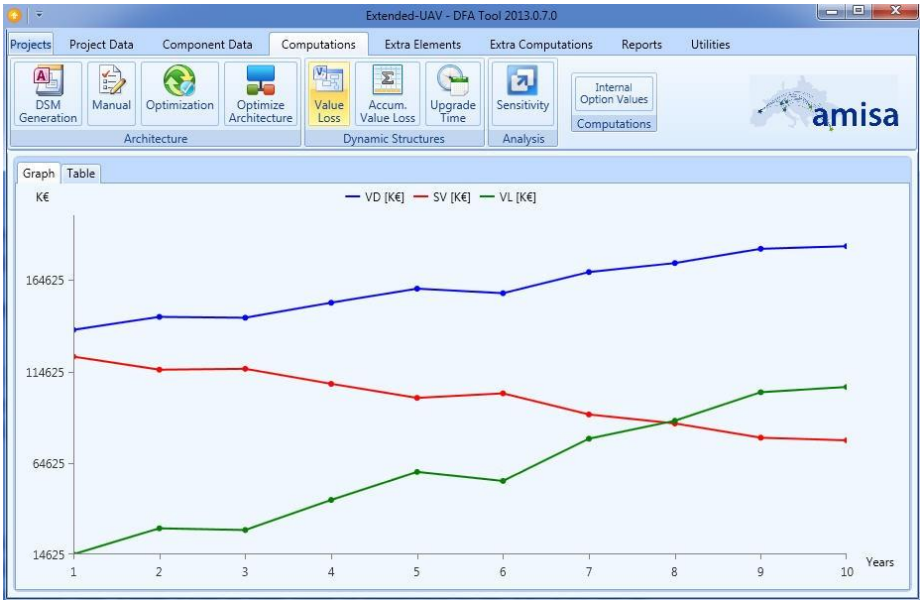


Figure 5-18 – Value loss computation – Graph

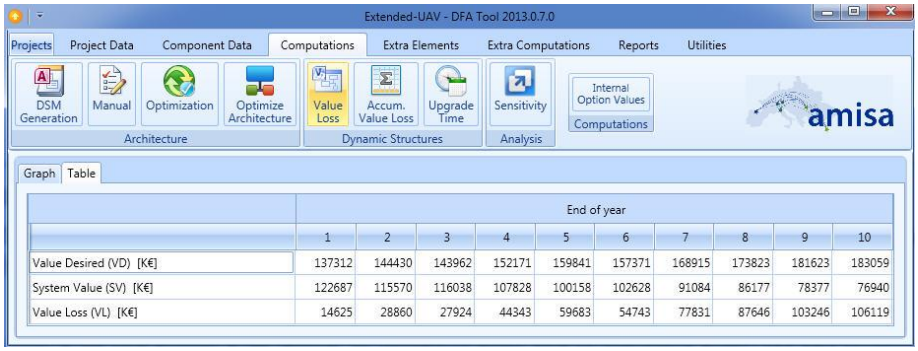


Figure 5-19 – Value loss computation – Table

5.2.2 Accumulated value loss

Figure 5-20 depicts, similar parameters discussed in the previous section namely: Value Desired (VD), System Value (SV) and Value Loss (VL). In addition, it shows the Accumulated Value Loss (AVL), that is, the accrued loss of value to stakeholders from the time the system was supplied until the end of any given year. This Accumulated Value loss may be expressed by the following equation:

$$AVL(t) = \frac{t * VL(t)}{2}$$

For example, using the data presented in the previous section the Accumulated Value loss at the end of the 10th year is expected to reach AVL=€528M.

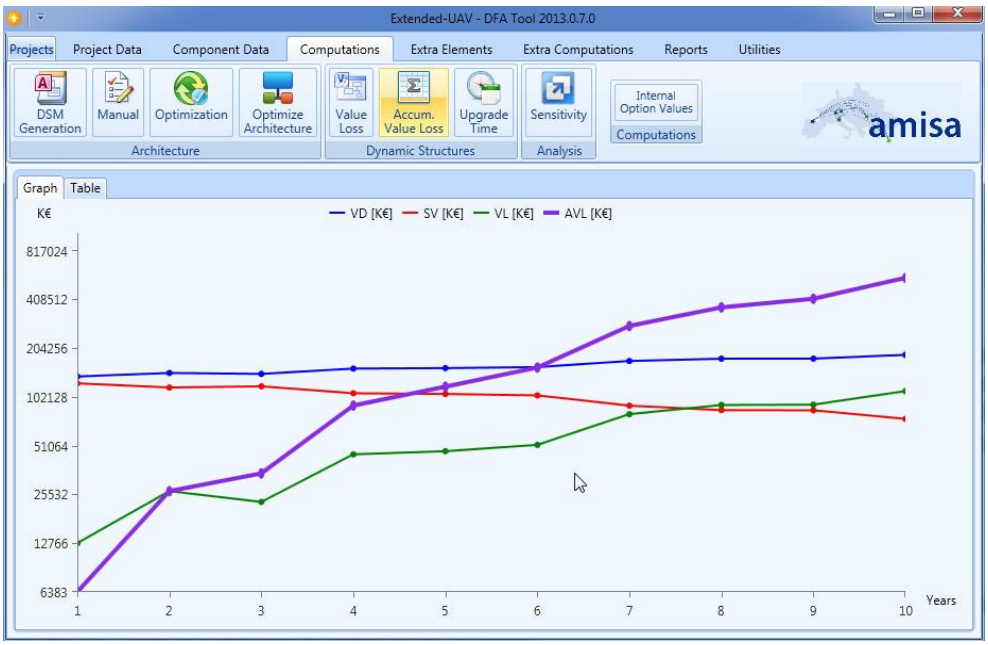


Figure 5-20 – Accumulated value loss

5.2.3 Upgrade time

Figure 5-21 depicts the increasing Upgrade Cost (UC) versus the much faster increasing Accumulated Value Loss (AVL). The user can determine the expected optimal time for system upgrade to be as soon as the Upgrade cost is less than the Accumulated Value Loss. In other words we seek:

$$\begin{aligned} &Min\ (t) \\ &Where:\ UC(t) \le AVL(t) \end{aligned}$$

For example, using the data presented in the previous section the optimal Upgrade Time is expected to be UT=5 years and the Upgrade Cost is expected to be UC=€116M.

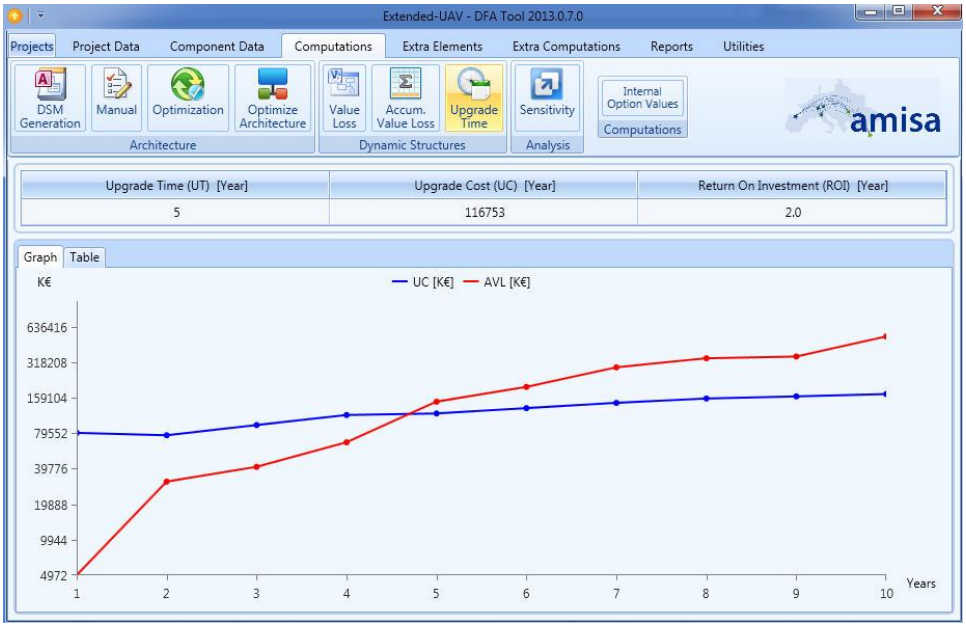


Figure 5-21 – Optimal upgrade time

5.3 Sensitivity analysis

The system architecture sensitivity analysis is based on the assumption that estimating Option Values (OVs) and Interfaces Costs (ICs) may be inexact. Therefore, users may like to perform sensitivity analysis in which different architectures may be generated as a result of changing slightly the expected OCs and ICs.

5.3.1 Explore system architectures space

The user can explore the space of system architectures by running the sensitivity analysis for a single iteration. This is done just to provide a general feel about the problem at hand before attempting to conduct serious sensitivity analysis.

5.3.1.1 Conduct exploration

Figure 5-22 depicts such an exploration where different combinations of OV and IC values are used. In this example, the selected range of OVs and ICs is ±30% from nominal (i.e. factored between 0.70 and 1.30). A map of 7x7=49 cells is generated where each cell identifies an Architecture Adaptability Value generated under different set of OV and IC. In addition, each cell contains a set-order (i.e. 1,2,…,49 in this example).

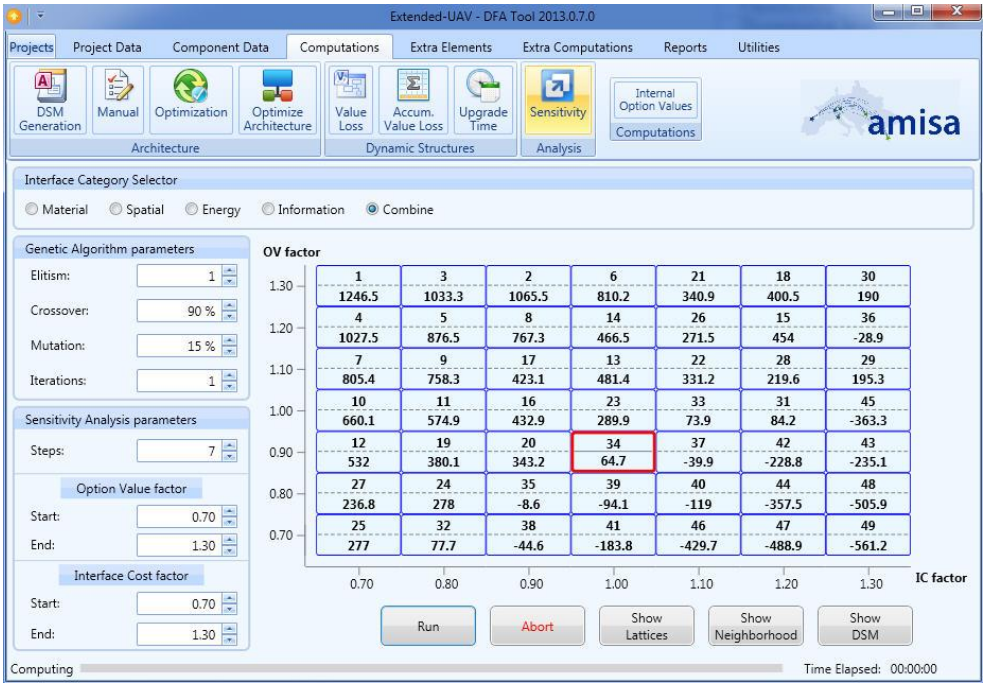


Figure 5-22 - Exploratory space of systems architectures

5.3.1.2 Show exploratory lattices

By clicking the "Show Lattices", we can generate an exploratory Lattice-graph diagram[3] (Figure 5-23) corresponding to the above set of exploratory systems architectures. A lattice-graph is a diagram whose vertices correspond to nodes and its edges correspond to links between nodes. In this diagram, each node defines unique system architecture. And, by definition, an upper level architecture subsumes a lower level architecture. Here, the square nodes indicate real system architectures and the rounded (S) nodes indicate surrogate (mathematically formed system architectures).

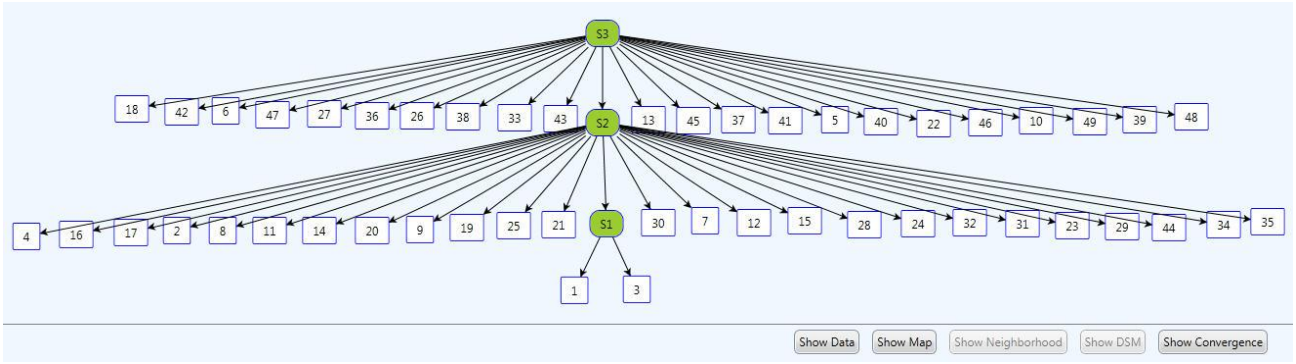


Figure 5-23 – An Exploratory lattice graph

3 From a mathematical standpoint, lattices represent multivariate data and algebraic structures, satisfying certain axiomatic identities. In particular, its data is a partially ordered set in which any two or more nodes: (1) Have a supremum (called "Join") and (2) Have an infimum (called "Meet") where each supremum subsume all its infima (See more: Davey and Priestley, 2002).

5.3.2 Conduct sensitivity analysis

The user can optimize a set of system architectures, using different combinations of OV and IC values.

5.3.2.1 Optimize the AAV set

Figure 5-24 depict the optimized results after 10,000 iterations for each combination of OVs and ICs in the ranges ±30%. This process may take some time as the DFA-Tool seeks to optimize each combination of OV and IC values (i.e. a total of 49 optimization settings for this example).

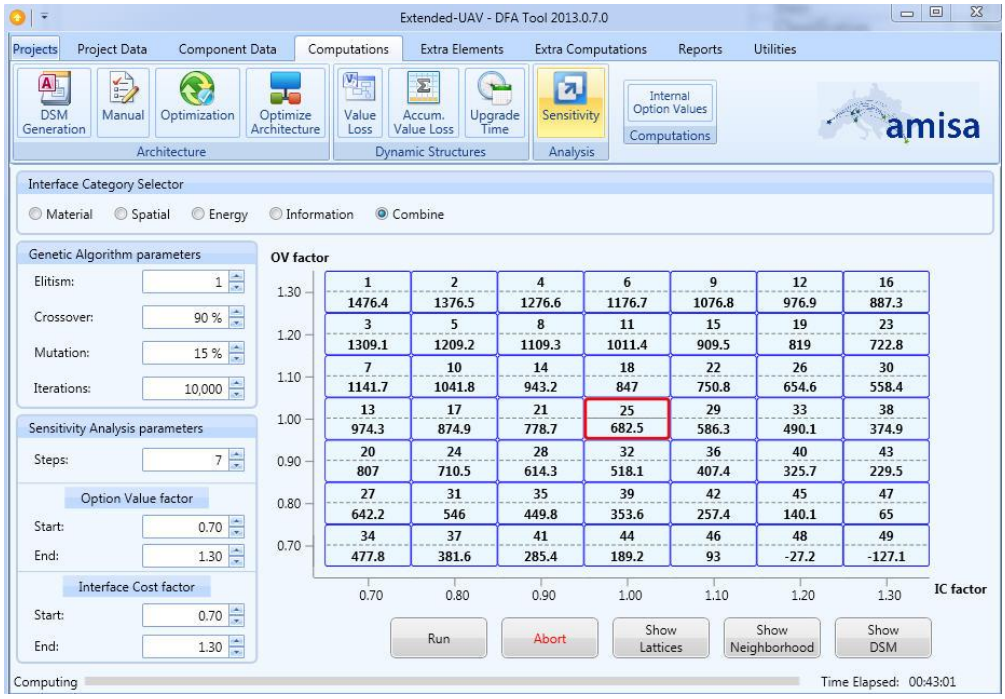


Figure 5-24 – Optimized sensitivity analysis

5.3.2.2 Show lattices

The user can display a Lattice-graph associated with the generated optimized AAVs by clicking the "Show Lattices" button. For example Figure 5-25 depicts a total of two individual optimized system architectures.

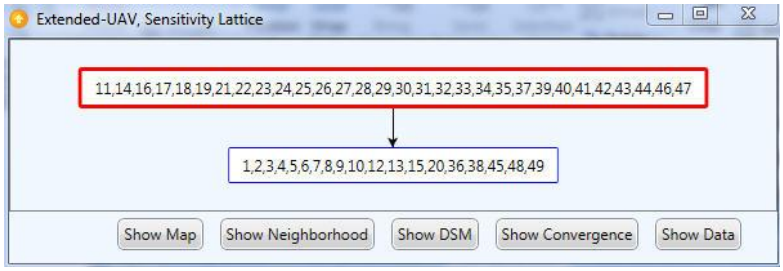


Figure 5-25 – Two optimal solutions lattice structure

5.3.2.3 Show neighborhood

The user can display individual cells' neighborhood by clicking on the desired cell (€682.5K) and then clicking the "Show Neighborhood" button. Figure 5-26 depicts the neighborhood of the optimized architecture (in real values or percent). That is, how the AAV of this architecture would change if the Option Values (OVs) and Interface Costs (ICs) estimated by the design engineer are, in fact, skewed. As can be seen, the nominal optimal AAV = 682.5 while the computed neighborhood creates a flat surface with a slope of 74.1 degrees relative to the horizon.

Figure 5-26 – Neighborhood of the optimized architecture

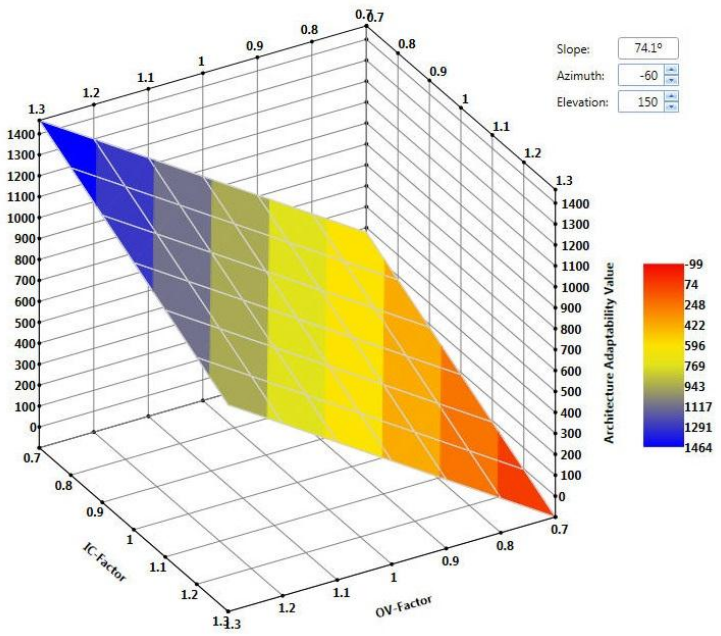
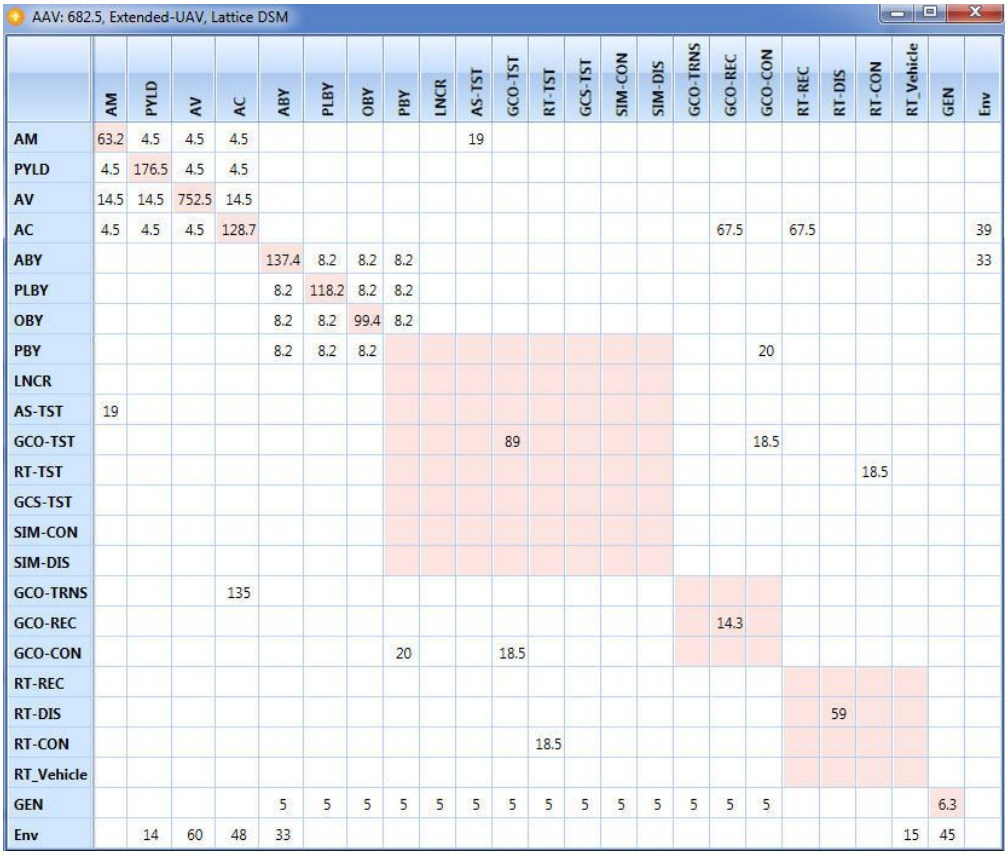


Figure 5-27 - 3-D graph of the optimized architecture neighborhood

5.3.2.4 Show DSM

The user can display any DSM associated with any cell by clicking first on the desired cell and then clicking the "Show DSM" button. Figure 5-28 depicts the DSM associated with optimized architecture AAV = €682.5K.



	AM	PYLD	AV	AC	ABY	PLBY	OBY	PBY	LNCR	AS-TST	GCO-TST	RT-TST	GCS-TST	SIM-CON	SIM-DIS	GCO-TRNS	GCO-REC	GCO-CON	RT-REC	RT-DIS	RT-CON	RT_Vehicle	GEN	Env
AM	63.2	4.5	4.5	4.5						19														
PYLD	4.5	176.5	4.5	4.5																				
AV	14.5	14.5	752.5	14.5																				
AC	4.5	4.5	4.5	128.7													67.5		67.5					39
ABY					137.4	8.2	8.2	8.2																33
PLBY					8.2	118.2	8.2	8.2																
OBY					8.2	8.2	99.4	8.2																
PBY					8.2	8.2	8.2											20						
LNCR																								
AS-TST	19																							
GCO-TST											89							18.5						
RT-TST																					18.5			
GCS-TST																								
SIM-CON																								
SIM-DIS																								
GCO-TRNS				135																				
GCO-REC																	14.3							
GCO-CON								20			18.5													
RT-REC																								
RT-DIS																				59				
RT-CON												18.5												
RT_Vehicle																								
GEN					5	5	5	5	5	5	5	5	5	5	5	5	5	5					6.3	
Env		14	60	48	33																	15	45	

Figure 5-28 – Optimized sensitivity analysis DSM

5.3.2.5 Analyze lattices chart

The user may utilize the lattices panel in order display a map of the optimized architecture or show either the neighborhood or DSM (as discussed above). For example, the user can display a map of the optimized architecture by clicking on the desired lattice (depicted in Figure 5-29) and then clicking the "Show Map" button. Figure 5-29 depicts a map identifying a single architecture which was created under 30 combinations of OVs and ICs. Since so many different combinations of OVs and ICs produce the same system architecture, one may conclude that this system architecture is quite robust.

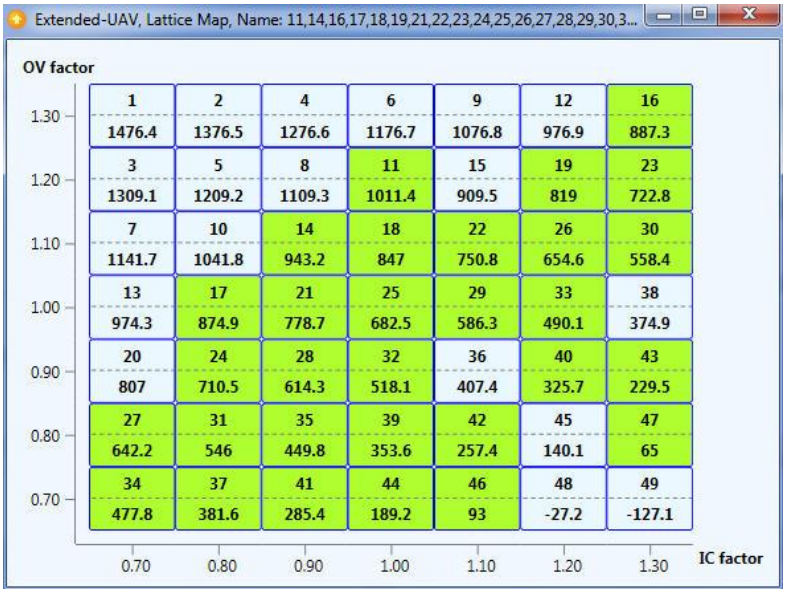


Figure 5-29 –Lattices map of optimized architecture

5.3.2.6 Convergence analysis

A critical dimension of solving nonlinear optimization problems is the definition of an appropriate stopping criterion for the search algorithm as well as ascertaining the level of global convergence achieved in the process. A stopping criterion should be rigorous enough so that we do not waste too much computing resources yet loose enough to ensure that, in most cases, the algorithm does not terminate before the global optimum has been reached. The problem is greatly exasperated because, in most practical problems, we do not know the optimal solution in advance and the volume of computations can have dramatic effects on the overall algorithm convergence.

We use the number of optimization iterations as the stopping criterion for the optimization process. For the UAV example, we initially set the stopping criterion at 10,000 optimization cycles. Next, we perform the optimization and sensitivity analysis and generate the relevant Sensitivity matrix as well as the Lattice diagram. Next, we compute a Neighborhood matrix for each optimal architecture, duplicating the OVs and ICs factors of the Sensitivity matrix. For the UAV example we have three such architectures (A, B and C).

We compare each cell in the Sensitivity matrix against a corresponding cell in the Neighborhood matrix of each optimized architecture. Obviously, Sensitivity matrix cells containing smaller Adaptability Architecture Values (AAVs) than any corresponding Neighborhood matrix cell indicate that, for that combination of OV and IC, a convergence has not been achieved.

Figure 5-30 depicts the Convergence matrix associated with the initial stopping criterion (10,000 optimization cycles). The Figure indicates that for 8 combinations of OVs and ICs, the algorithm stopped before a convergence has been achieved. Increasing the optimization stopping criterion to 50,000 iterations eliminated all the non-converging cells in the Convergence matrix.

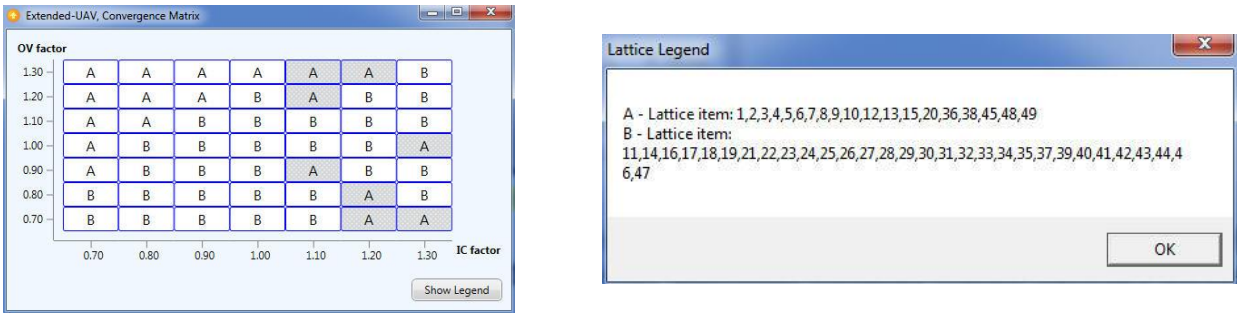


Figure 5-30 – Convergence matrix derived from the original stopping criterion

6. Extra elements (Variant systems)

This section deals with the definition of families of variant systems. That is, systems that are similar to a given base-system, but have either additional elements (called *Auxiliary elements*) or elements which replace existing elements in the base system (called *Variant elements*). This section of the DFA-Tool consists of the following elements: (1) Introduction, (2) Auxiliary Data, (3) Variant Data and (4) Interface Data (see below).

6.1 Introduction

The implementation of the Variant system is explained by means of a portion of a UAV example. Figure 6-1 depicts a portion of the original (base) UAV system.

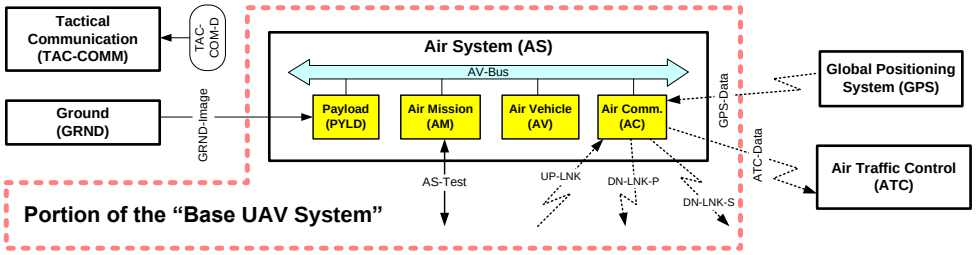


Figure 6-1 – Portion of original (base) UAV system

The Variant UAV system, depicted in Figure 6-2, has been developed for public use depicting urban and agriculture land-use. Two Air-Vehicle components were replaced. The original day/night payload was replaced with a multi-spectral sensor and the original narrow-beam Air Communication component was replaces with a 360^{o} wide-beam transmitter. In addition, appropriate interfaces have been replaced.

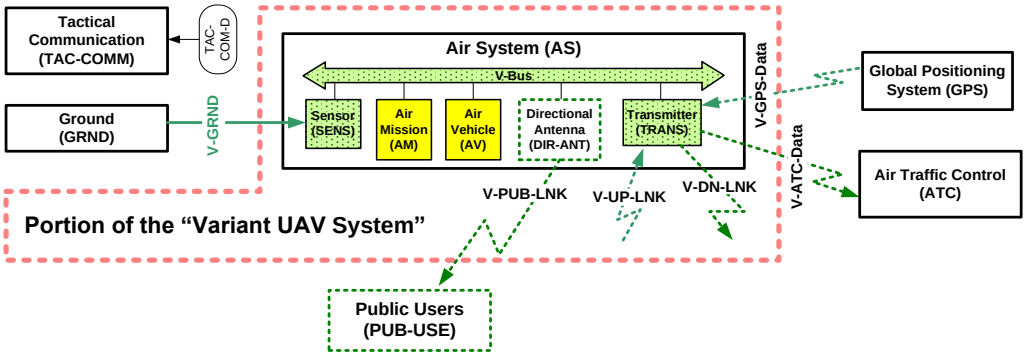


Figure 6-2 – Portion of Variant UAV system

6.2 Auxiliary data

6.2.1 Auxiliary elements

The Auxiliary element definition GUI is depicted in Figure 6-7. The user can define Auxiliary components and Auxiliary environment. Each Auxiliary element is a completely new element in the system (i.e. not defined in the base system). The user can Add/Modify/Delete Auxiliary element using similar procedure relevant to the base components.

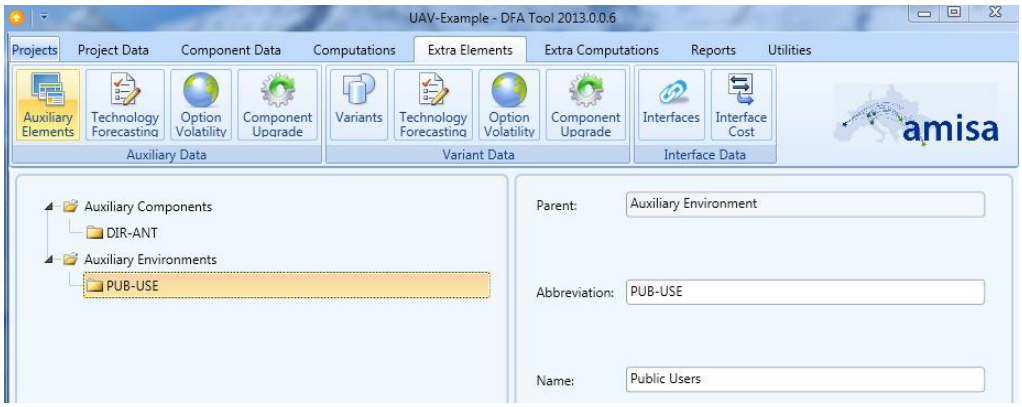


Figure 6-3 – Auxiliary element definition GUI

6.2.2 Technology forecasting

The user can Add/Modify/Delete the Auxiliary Technology forecasting using similar procedure relevant to the base components. In addition, on creation of Technology forecasting, the user can copy Technology forecasting data from an existing component and then keep this data or modify it as needed (Figure 6-8).

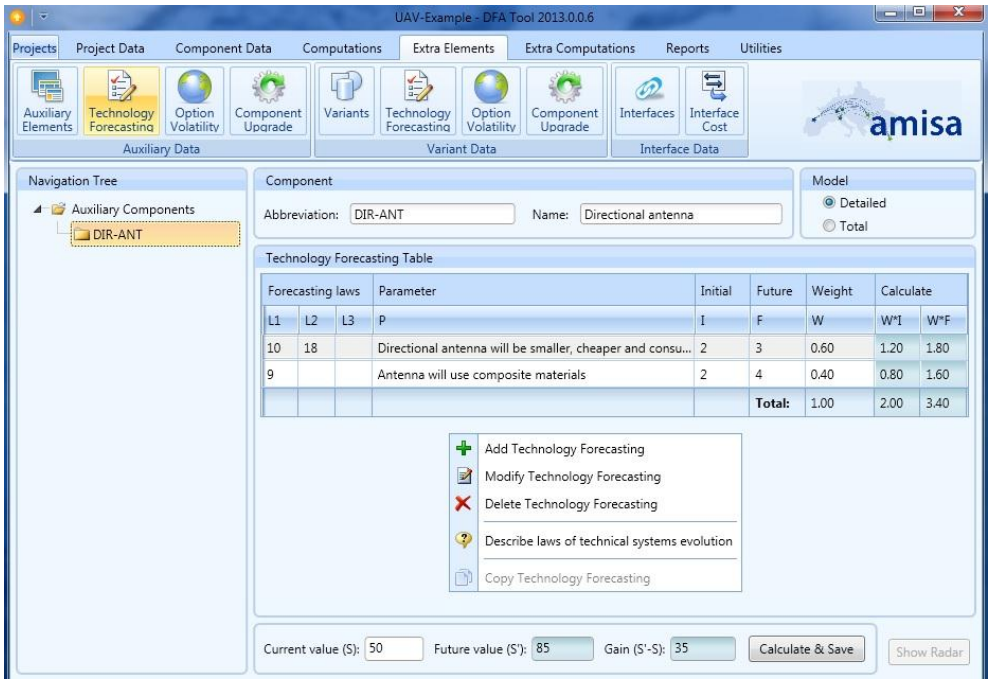


Figure 6-4 – Auxiliary Technology forecasting GUI

6.2.3 Option Volatility

The user can Add/Modify/Delete the Auxiliary Option Volatility using similar procedure relevant to the base components. In addition, on creation of Option Volatility, the user can copy Option Volatility data from an existing component and then keep this data or modify it as needed (Figure 6-5).

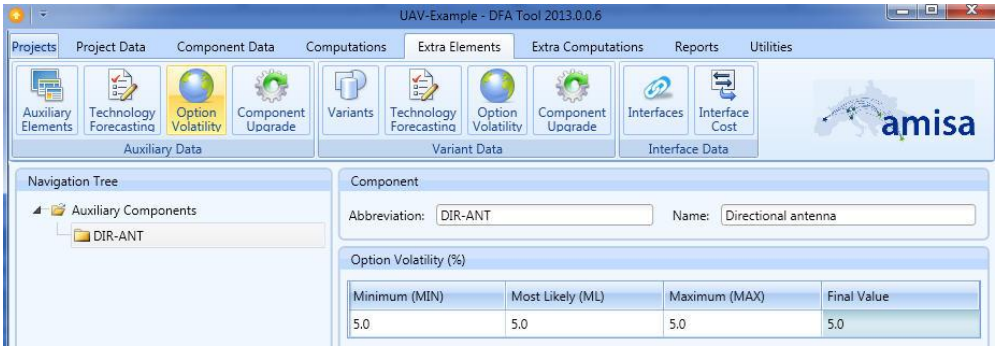


Figure 6-5 – Auxiliary Option volatility GUI

6.2.4 Component upgrade

The user can Add/Modify/Delete Component upgrade data using similar procedure relevant to the base components. In addition, on creation of Component upgrade, the user can copy Component upgrade data from an existing component and then keep this data or modify it as needed (Figure 6-6).

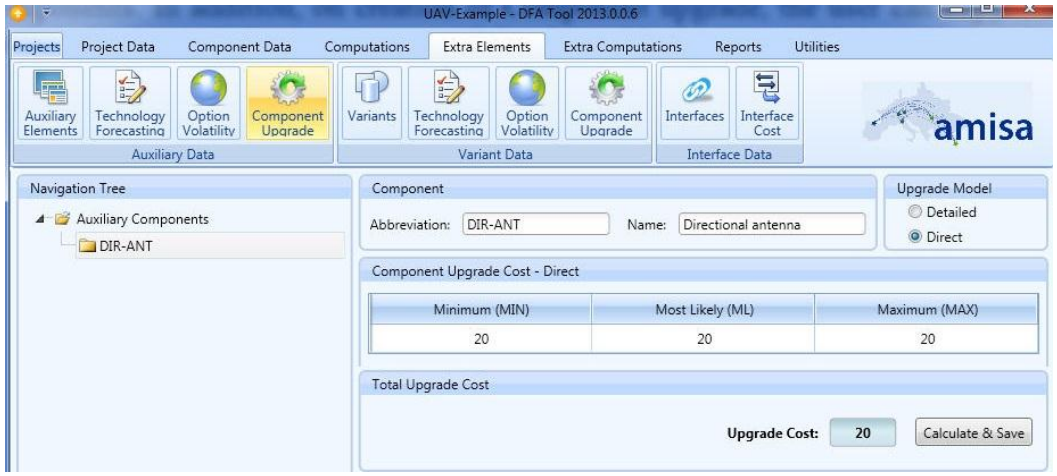


Figure 6-6 – Auxiliary Component upgrade GUI

6.3 Variant data

6.3.1 Variant elements

The Variants elements definition GUI is depicted in Figure 6-7. The user can define variant components and variant environment. Each variant element is always associated with a corresponding existing (base) element.

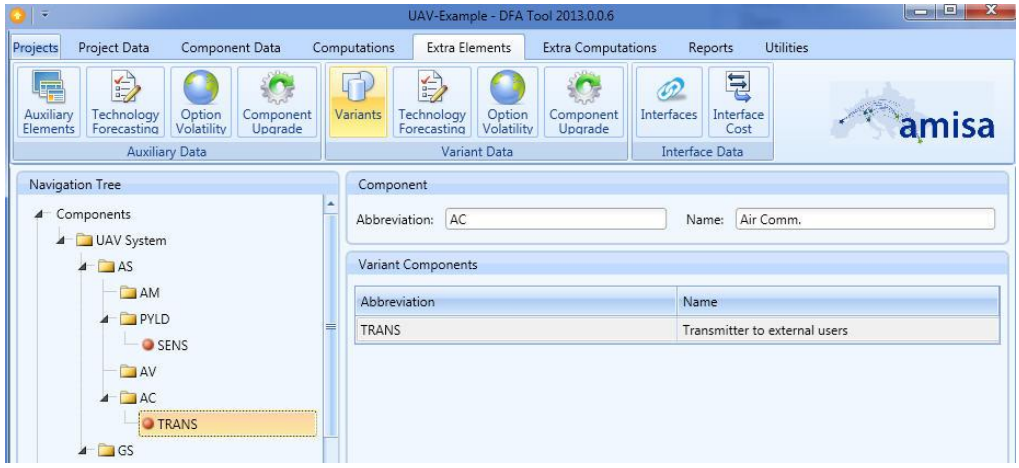


Figure 6-7 - Variant elements definition GUI

6.3.1.1 Procedure

The procedure to Modify/Add/Delete Variant components is carried out following these steps:

- Step-1: Click on the Variants icon in the Variant section of the DFA-Tool.
- Step-2: Use the Navigation tree on the left hand side of the display to select an existing (base) component.
- Step-3: Components with existing variants are identified with a small orange circle. You may modify (edit) directly an abbreviation or a name of an existing variant component.

- Step-4: The DFA-Tool prevents using illegal (or used) abbreviations or names of variant components. You must enter correct and unused names or abort the addition process using the Escape key.
- Step-5: Right-click on the variant component area and either Add new variant component or identify and Delete an existing variant component. Each new variant component will be associated with a base component.
- Users should note that, by definition, each system variant may include either the base component or one and only one of the variant components.

6.3.1.2 Example

Figure 6-7 depicts an example whereby the base component is the Air Comm. (AC). The variant component is a different transmitter (TRANS), defined in association with the base component. The implication of this definition is that there could be two types of system variants, each using either transmitter AC or transmitter TRANS.

6.3.2 Technology forecasting

On creating a variant component, a Technology forecasting data is automatically copied from the corresponding base component into the database (Figure 6-8). The user may keep this data or copy it from another base component or modify it as needed.

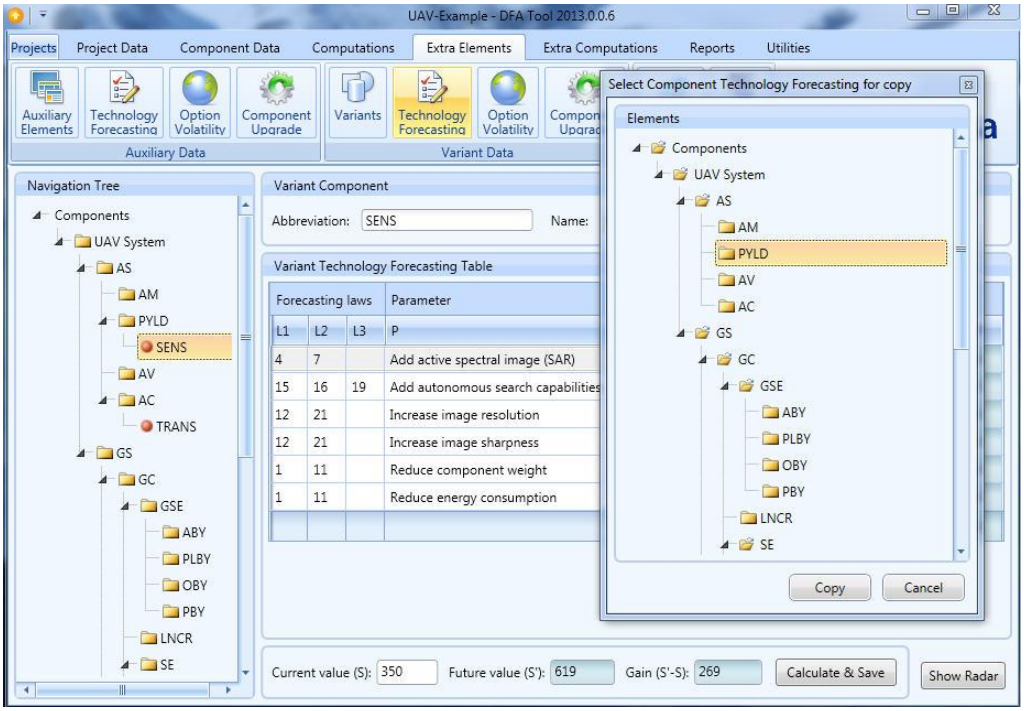


Figure 6-8 – Variant Technology forecasting GUI

6.3.3 Option Volatility

On creating a variant component, an Option volatility data is automatically copied from the corresponding base component into the database. The user may keep this data or copy it from another base component or modify it as needed.

6.3.4 Component upgrade

On creating a variant component, a Component upgrade data is automatically copied from the corresponding base component into the database. The user may keep this data or copy it from another base component or modify it as needed.

6.4 Interface data

6.4.1 Interfaces

The Auxiliary/Variants interfaces definition GUI is depicted in Figure 6-9. The user can define Auxiliary or Variant interfaces connecting either existing (base) components with Auxiliary/Variant components or Auxiliary/Variant components with other Auxiliary/Variant components. Users should note that the DFA-Tool will require at least one Auxiliary/Variant component in any definition of such interfaces.

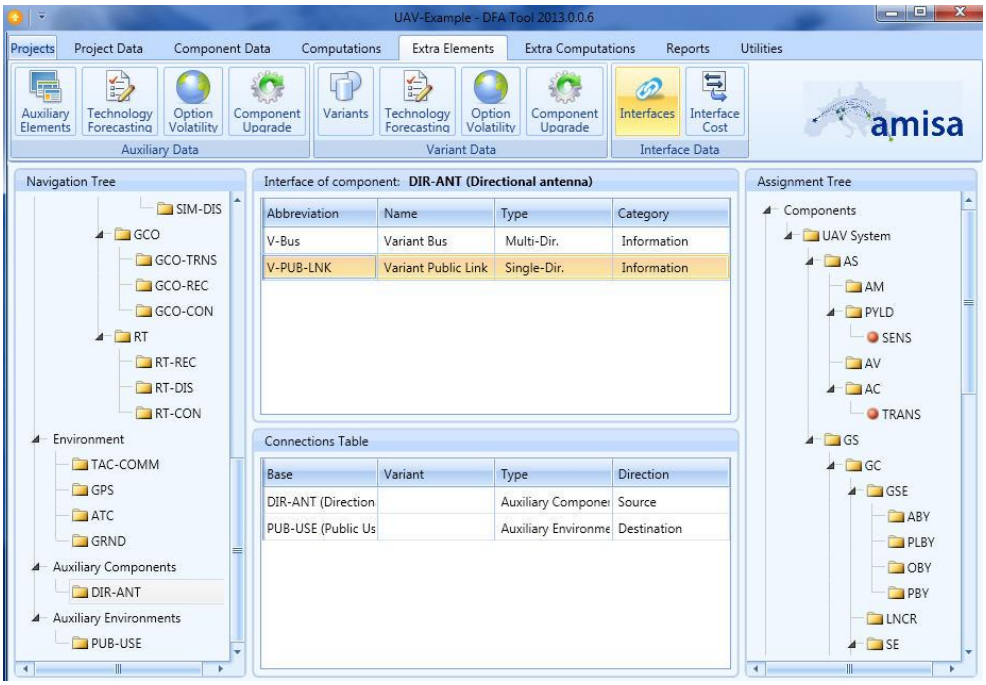


Figure 6-9 – Auxiliary/Variant interfaces definition GUI

6.4.1.1 Procedure

The procedure to Modify/Add/Delete Auxiliary/Variant interface is carried out following these steps:

- Step-1: Click on the Interfaces icon in the Extra elements section of the DFA-Tool.

1. **<u>For selecting variants:</u>**
   - Step-2: Use the Navigation tree on the left hand side of the display to select an existing (base) component.
   - Step-3: If the selected base component has one or more variants (identified with a small orange circle), then you must identify which component/variant will initiate the interface.

This is done by right-clicking and selecting the desired element. The name of the selected element will appear at the top of the interface list.

2. **For selecting auxiliary:**
   - Step-4: Use the Navigation tree on the left hand side of the display to select an auxiliary component.

- Step-5: Build the connection table by defining either components or auxiliary or variant components from the Assignment tree by right-clicking and selecting the desired element.
- Step-6: Users must note that the DFA-Tool will accept only auxiliary/variant interfaces containing one or more auxiliary or variant component in their definition.

6.4.1.2 Example

Figure 6-9 depicts an example whereby an auxiliary component DIR-ANT was added to the UAV variant system. A new interface V-PUB-LNK was created, connecting this auxiliary component DIR-ANT to the auxiliary environment PUB-USE.

6.4.2 Interface cost

The user can manually create or copy an existing Interface cost data into the database (Figure 6-10).

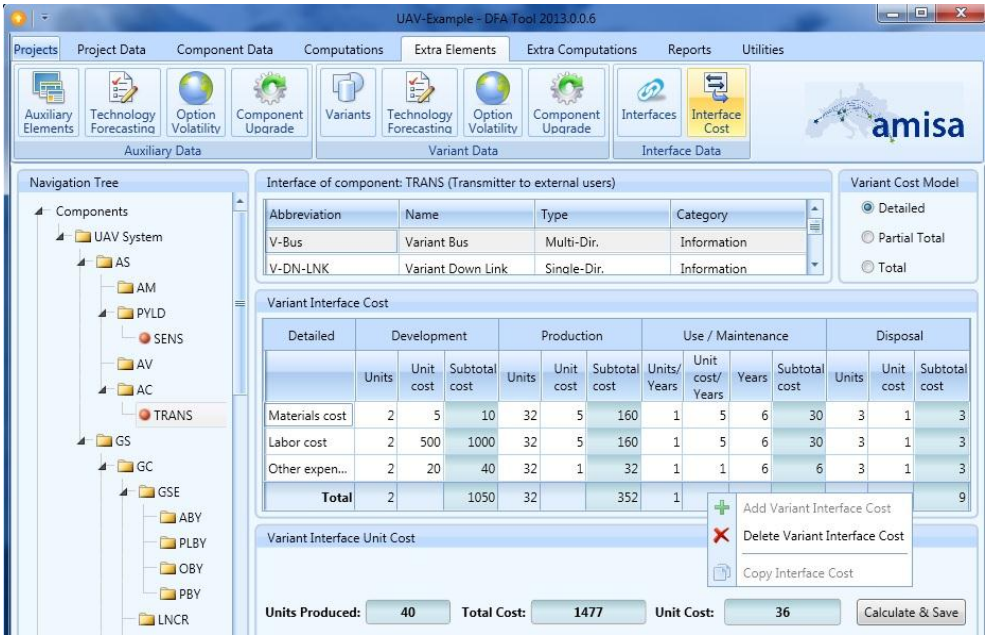


Figure 6-10 – Variant add/copy Interface cost

6.4.2.1 Procedure

- Step-1: The user may select to add interface cost data manually or copy this data from an existing base component (Figure 6-11). In this case:

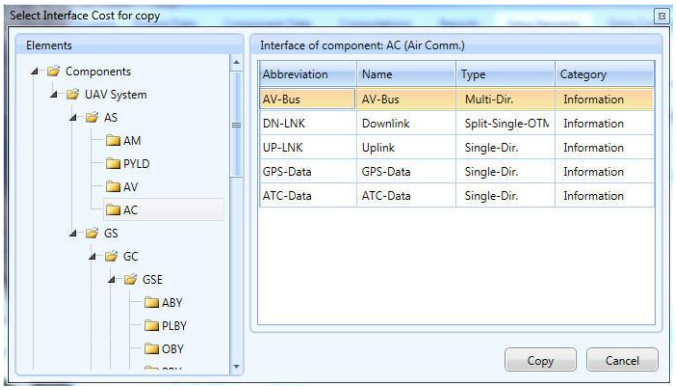


Figure 6-11 – Copying existing interface cost data

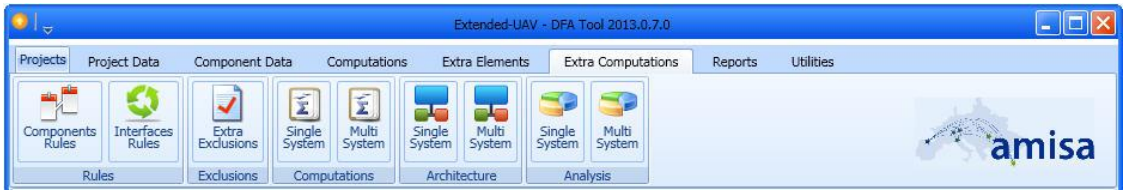
- Step-2: The user will travel along the Navigation tree and select a desired base component.
- Step-3: The user will select desired base interface and click "Copy"
- Step-4: The desired interface cost is copied into the database.
- Step-5: User may keep this data or modify it as needed.

6.4.2.2 Example

In the example, we like to define the interface cost of the V-Bus (connected, among other, to the TRANS) as depicted in Figure 6-10. We use the copy facility in order to copy available interface cost data from interface AV-Bus as depicted in Figure 6-11.

7. Extra computations (Variant systems)

This section deals with the calculations, analysis and display of families of variant systems. This section of the DFA-Tool consists of the following elements: (1) Rules, (2) Extra Exclusions, (3) Computations, (4) Architecture and (5) Analysis (see below).



7.1 Rules

7.1.1 Components rules

The Auxiliary/Variants components rules definition GUI is depicted in Figure 7-1. The user can create project-wide definitions of Auxiliary/Variant rules which define the specific Components, Auxiliary or Variants dependencies for each the system variant.

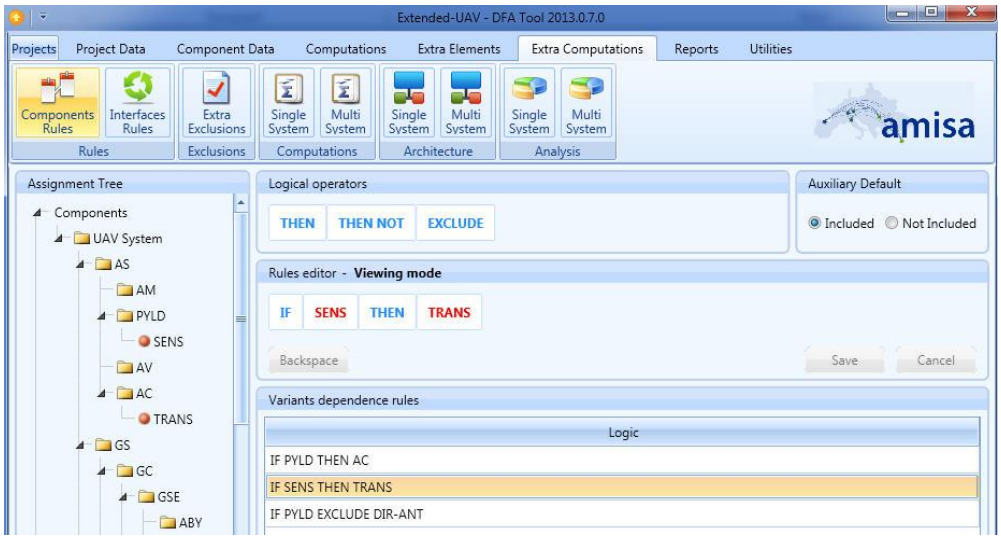


Figure 7-1 - Variant components rules definition GUI

7.1.1.1 Procedure

The procedure to Add/Modify/Delete Auxiliary/Variant components rules is carried out following these steps:

- Step-1: The user can select the default handling of auxiliary components using the right-hand side "Auxiliary Default" box. If the "Included" mode is selected, all auxiliary components are included in all system variants unless they are specifically excluded using relevant rules. However, if the "Not Included" mode is selected, all auxiliary components are not included in all system variants unless they are specifically included using relevant rules. This may sometimes be important in order to decrease the number of rules.
- Step-2: Click on the Components rules icon in the Extra computation segment of the DFA-Tool.
- Step-3: Use the Rules editor to create one or more Auxiliary/Variant combination rules. Rules are composed of a sequence of component or auxiliary or variant abbreviations interspersed with a logical operator. They will be used to create different variant systems.
- Step-4: Use the Assignment tree on the left hand side of the display to select an existing (base) component. If the selected base component has one or more variants (identified with a small orange circle), then you should identify which component/variant should by moved into the rules editor area. This is done by right-clicking and selecting the desired element.
- Step-5: If you need to insert an auxiliary element just select it via right-click.
- Step-6: Use the logical operators table to select an appropriate logical operator and move it into the rules editor area. This is done by right-clicking the desired logical operator.
- Step-7: You can modify an existing rule by identifying it and then right-click and select "Modify rule". Thereafter, you may add component/auxiliary/variant or logical operator at the end of the existing rule chain. Conversely, you can use the rules editor Backspace to delete successively individual elements in the rule editor area from right to left.
- Step-8: You may delete any rule by identifying it and then right click, selecting the Delete rule.

7.1.1.2 Example

Figure 7-1 depicts an example whereby three components rules have been defined. Essentially, each variant rule ensures a specific combination of payload/sensor with a corresponding transmitter i.e. {PYLD and AC} or {SENS and TRANS}. The third rule ensures that the Auxiliary antenna (DIR-ANT), will be excluded in the base UAV system but will be a part of the variant UAV system.

7.1.2 Interface rules

The Interface rules definition GUI is depicted in Figure 7-2. The user can create project-wide definitions of Auxiliary/Variant rules which define the specific Components, Auxiliary or Variants dependencies for each the system variant.

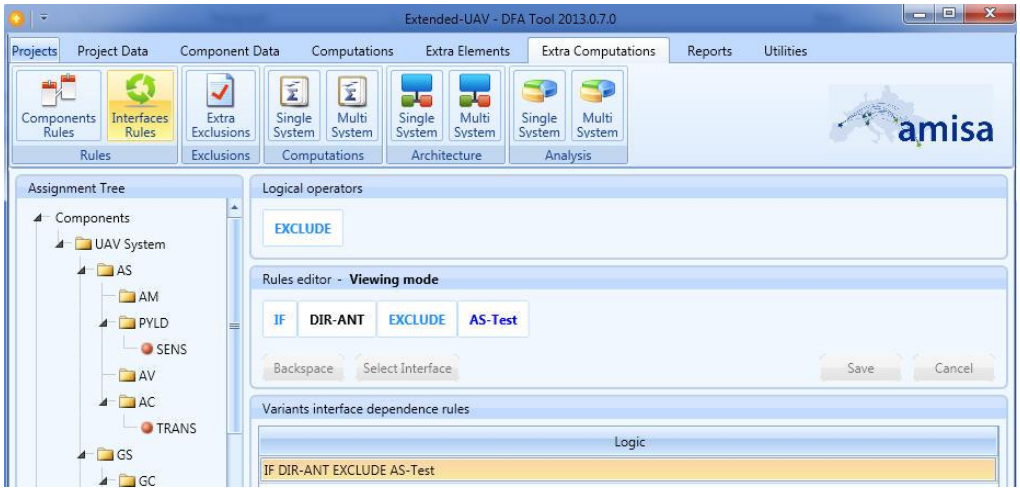


Figure 7-2 - Interface rules definition GUI

The procedure to define interface rules is similar to the procedure to define Auxiliary/Variants components rules however; the name of the interface itself must be selected from an interface table. The user may display this table by right-clicking the "Select Interface" button. Thereafter the user can move along the element tree, select an element and then select an interface (see Figure 7-3)

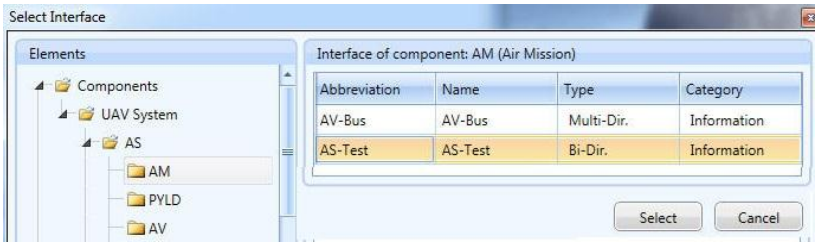


Figure 7-3 – Selection of Interface for Interface rules definition

In the example depicted in Figure 7-2 and Figure 7-3, the interface rule indicates that interface AS-Test is not part of the variant UAV system.

7.2 Extra exclusions

The Extra Exclusion definition GUI is depicted in Figure 7-4. By definition, each variant component is placed in the same exclusion segment of its base component (e.g. the variant component "SENS" will be placed in the same exclusion segment as "PYLD", which is "Air Vehicle System". The user

can however assign auxiliary components into a desired exclusion segment. For example, the "DIR-ANT" is assigned to the "Air Vehicle System" exclusion segment.

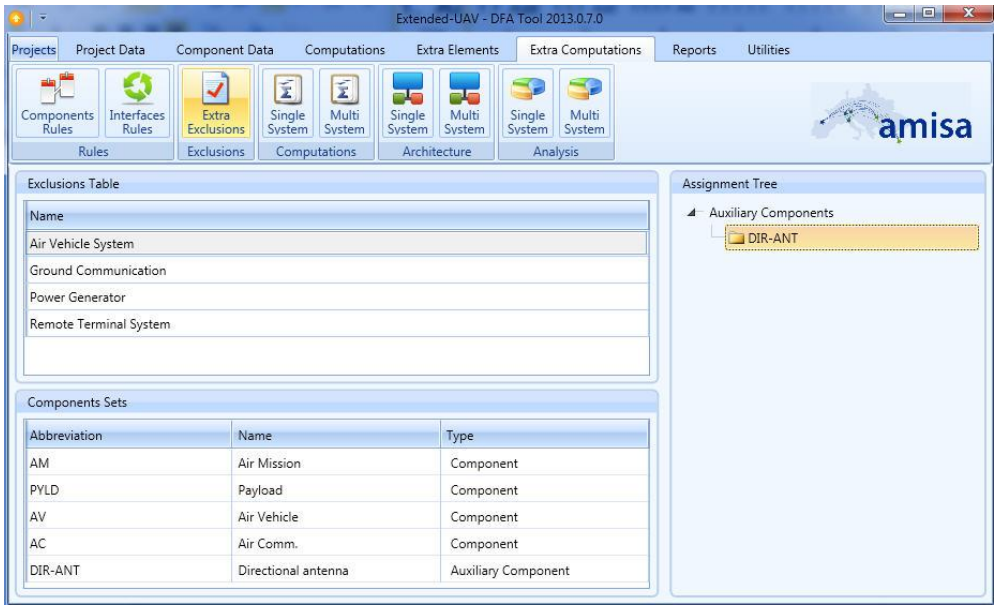


Figure 7-4 – Auxiliary exclusion definition GUI

7.3 Computations

7.3.1 Single system

Under Single system mode, the user can: (1) observe the components of each system variant and (2) compute and display the DSM and optimized DSM of each system variant. Figure 7-5 depicts (some of) the elements of the UAV variant system-2. Variant components are identified in Red color and Auxiliary components are identified in Blue color.

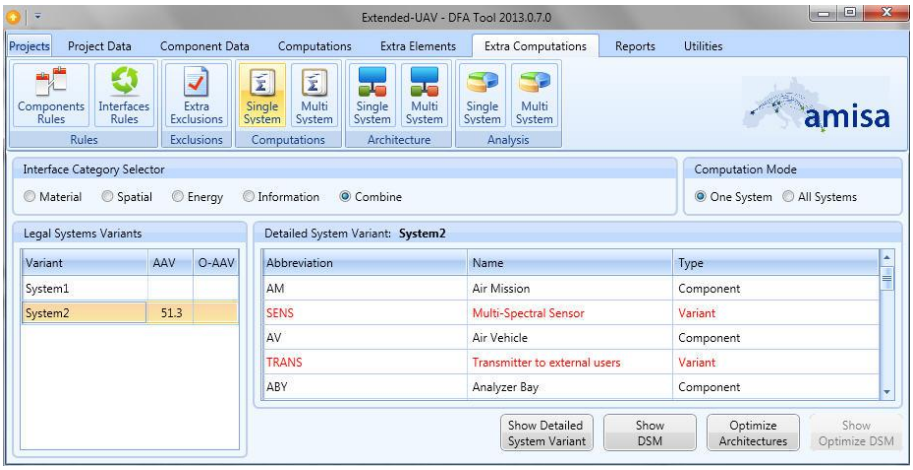


Figure 7-5 – Components of the Variant UAV system-2

Figure 7-6 depicts the DSM of the UAV variant system-2, using similar coloring scheme.

AAV: 51.3, Extended-UAV, Variant DSM, System2

	AM	SENS	AV	TRANS	ABY	PLBY	OBY	PBY	LNCR	AS-TST	GCO-TST	RT-TST	GCS-TST	SIM-CON	SIM-DIS	GCO-TRNS	GCO-REC	GCO-CON	RT-REC	RT-DIS	RT-CON	RT_Vehicle	GEN	DIR-ANT	Env
AM	63.2	3.6	3.6	3.6																				3.6	
SENS	3.6	102.6	3.6	3.6																				3.6	
AV	18.6	18.6	752.5	18.6																				18.6	
TRANS	3.6	3.6	3.6	76.8													135							3.6	66
ABY					137.4	8.2	8.2	8.2																	33
PLBY					8.2	118.2	8.2	8.2																	
OBY					8.2	8.2	99.4	8.2																	
PBY					8.2	8.2	8.2	80.4	42.5				18.5	17.5				20							
LNCR								42.5	4.8																
AS-TST										18.7	8.8	8.8	8.8												
GCO-TST										8.8	18.7	8.8	8.8					18.5							
RT-TST										8.8	8.8	18.7	8.8								18.5				
GCS-TST								18.5		8.8	8.8	8.8	18.7												
SIM-CON								17.5						3.1	17.5										
SIM-DIS														17.5	5										
GCO-TRNS				135												9.1		17.5							
GCO-REC																	9.1	18							
GCO-CON								20			18.5					17.5	18	6.4							
RT-REC																			38.2	11.2	11.2				
RT-DIS																			11.2	21.6	11.2				
RT-CON												18.5							11.2	11.2	39.4				
RT_Vehicle																			16.7	16.7	16.7	2			
GEN					5	5	5	5	5	5	5	5	5	5	5	5	5	5					6.3		
DIR-ANT	3.6	3.6	3.6	3.6																				20.2	135
Env		14	60	48	33																	15	45		

Figure 7-6 – DSM of the UAV variant system

Figure 7-7 depicts the single system optimization GUI assigned to the variant UAV system-2.

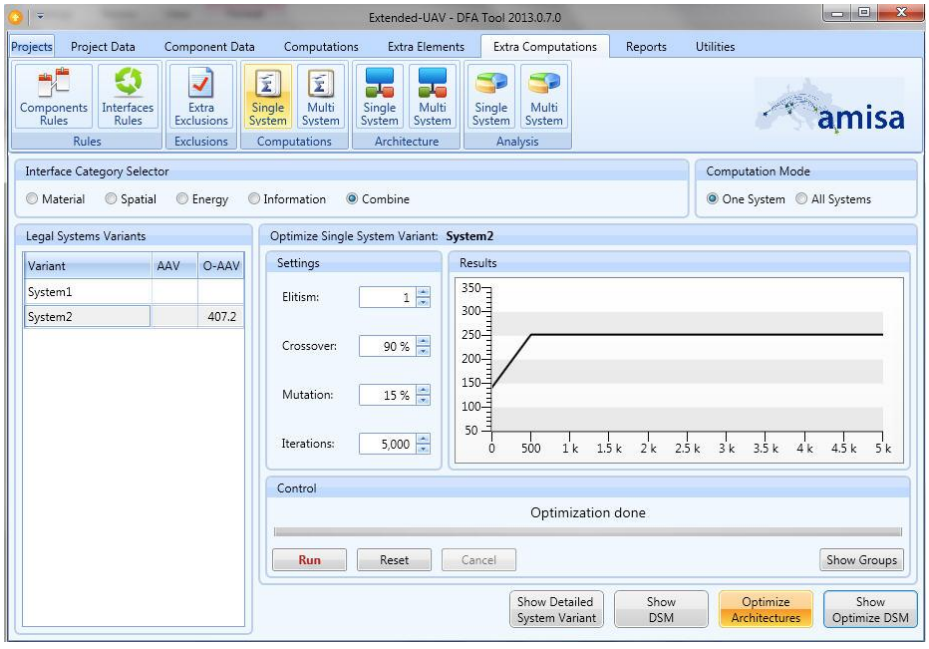
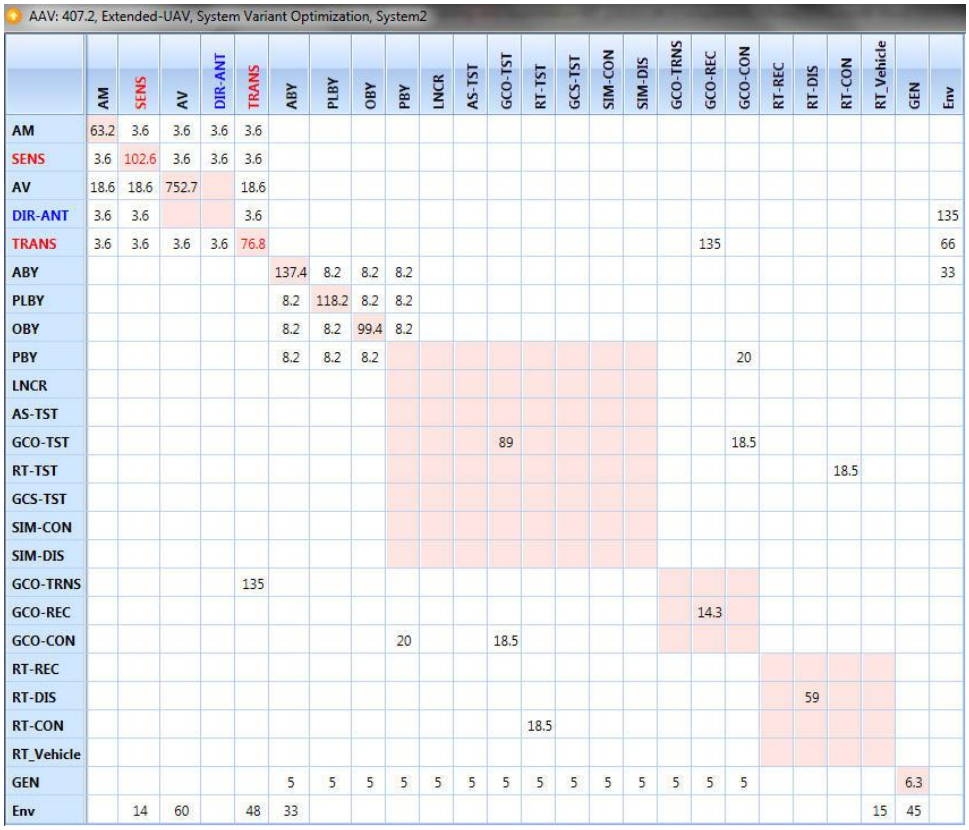


Figure 7-7 – Single system optimization GUI - Variant UAV system

Figure 7-8 depicts the optimized DSM of the UAV variant system-2.

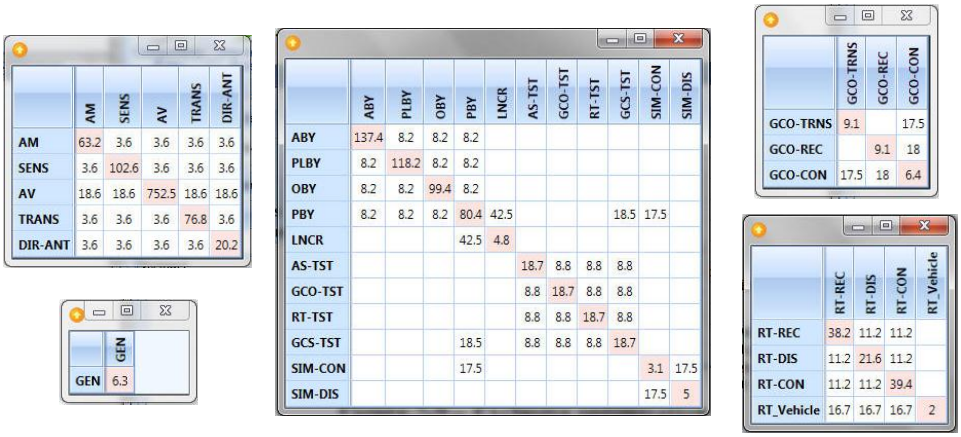


AAV: 407.2, Extended-UAV, System Variant Optimization, System2

	AM	SENS	AV	DIR-ANT	TRANS	ABY	PLBY	OBY	PBY	LNCR	AS-TST	GCO-TST	RT-TST	GCS-TST	SIM-CON	SIM-DIS	GCO-TRNS	GCO-REC	GCO-CON	RT-REC	RT-DIS	RT-CON	RT_Vehicle	GEN	Env
AM	63.2	3.6	3.6	3.6	3.6																				
SENS	3.6	102.6	3.6	3.6	3.6																				
AV	18.6	18.6	752.7		18.6																				
DIR-ANT	3.6	3.6			3.6																				135
TRANS	3.6	3.6	3.6	3.6	76.8													135							66
ABY						137.4	8.2	8.2	8.2																33
PLBY						8.2	118.2	8.2	8.2																
OBY						8.2	8.2	99.4	8.2																
PBY						8.2	8.2	8.2											20						
LNCR																									
AS-TST																									
GCO-TST												89							18.5						
RT-TST																						18.5			
GCS-TST																									
SIM-CON																									
SIM-DIS																									
GCO-TRNS					135																				
GCO-REC																		14.3							
GCO-CON									20			18.5													
RT-REC																									
RT-DIS																					59				
RT-CON													18.5												
RT_Vehicle																									
GEN						5	5	5	5	5	5	5	5	5	5	5	5	5	5					6.3	
Env		14	60		48	33																	15	45	

Figure 7-8 – Optimized DSM of the UAV variant system (Single system)

The user can click the "Show Groups" button in order to see the exclusive optimization groups (Figure 7-11). Each group is mutually exclusive from the other group for the purpose of DFA optimization.



	AM	SENS	AV	TRANS	DIR-ANT
AM	63.2	3.6	3.6	3.6	3.6
SENS	3.6	102.6	3.6	3.6	3.6
AV	18.6	18.6	752.5	18.6	18.6
TRANS	3.6	3.6	3.6	76.8	3.6
DIR-ANT	3.6	3.6	3.6	3.6	20.2

	GEN
GEN	6.3

	ABY	PLBY	OBY	PBY	LNCR	AS-TST	GCO-TST	RT-TST	GCS-TST	SIM-CON	SIM-DIS
ABY	137.4	8.2	8.2	8.2							
PLBY	8.2	118.2	8.2	8.2							
OBY	8.2	8.2	99.4	8.2							
PBY	8.2	8.2	8.2	80.4	42.5				18.5	17.5	
LNCR				42.5	4.8						
AS-TST						18.7	8.8	8.8	8.8		
GCO-TST						8.8	18.7	8.8	8.8		
RT-TST						8.8	8.8	18.7	8.8		
GCS-TST				18.5		8.8	8.8	8.8	18.7		
SIM-CON				17.5						3.1	17.5
SIM-DIS										17.5	5

	GCO-TRNS	GCO-REC	GCO-CON
GCO-TRNS	9.1		17.5
GCO-REC		9.1	18
GCO-CON	17.5	18	6.4

	RT-REC	RT-DIS	RT-CON	RT_Vehicle
RT-REC	38.2	11.2	11.2	
RT-DIS	11.2	21.6	11.2	
RT-CON	11.2	11.2	39.4	
RT_Vehicle	16.7	16.7	16.7	2

Figure 7-9 – Exclusive optimization groups (Single system)

The computations of DSMs can be performed automatically for the entire set of system variants (Figure 7-10) or individually by selecting a specific variant.

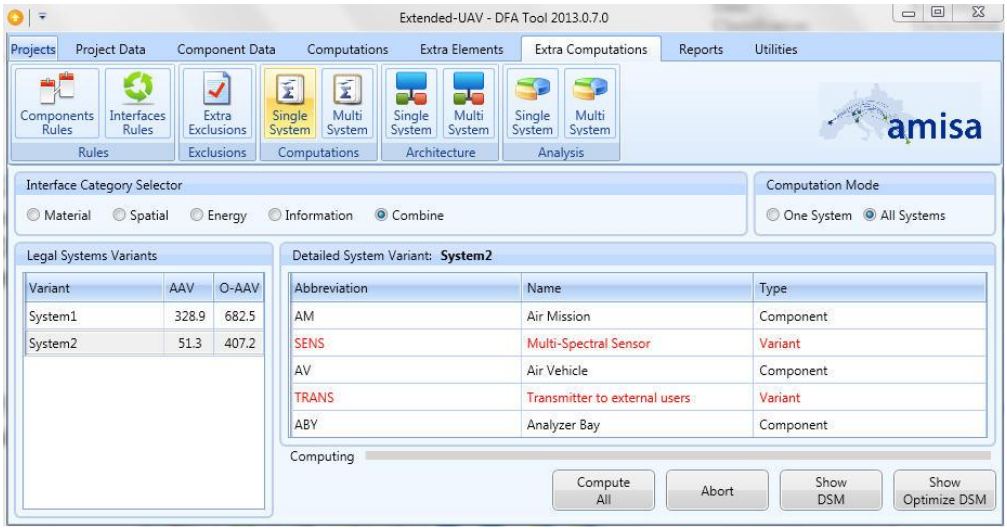


Figure 7-10 – Computations of all DSM and optimized DSM variants

7.3.2 Multi-system

Under Multi system mode, the user can select some or all the legal system variants by identifying the candidate variant systems in the "Legal System Variants" table. Figure 7-11 depicts the common components in the selected variant systems set. Regular components are depicted in black color, variant components are depicted in red color and auxiliary components are depicted in blue color.

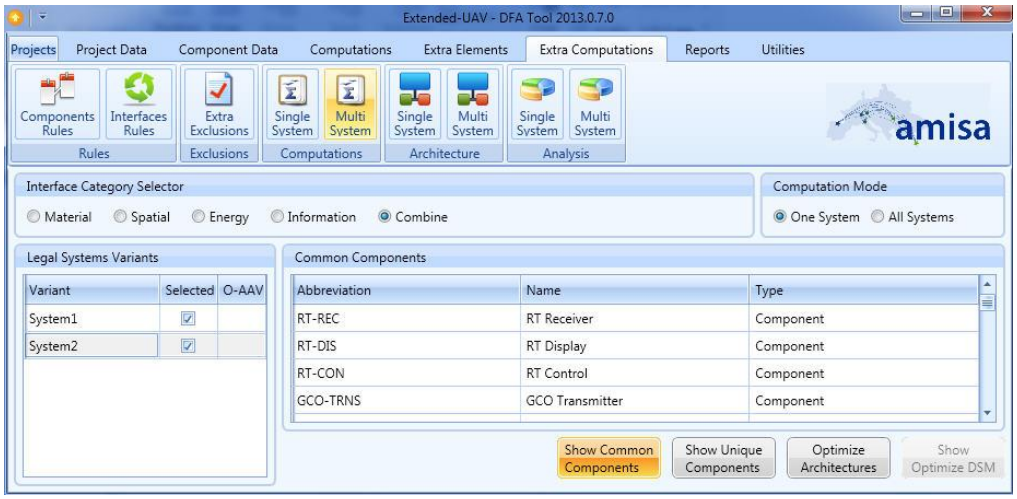


Figure 7-11 – Common components in the variants system set

Similarly, Figure 7-12 depicts the unique components in the selected variant systems set. Regular components are depicted in black color, variant components are depicted in red color and auxiliary components are depicted in blue color.

Figure 7-12 - Unique components in the variants system set

Figure 7-13 depicts the Multi system optimization GUI applied to the Variant UAV system. Under this mode all the unique components cannot create modules with other components so they remain standalone components.

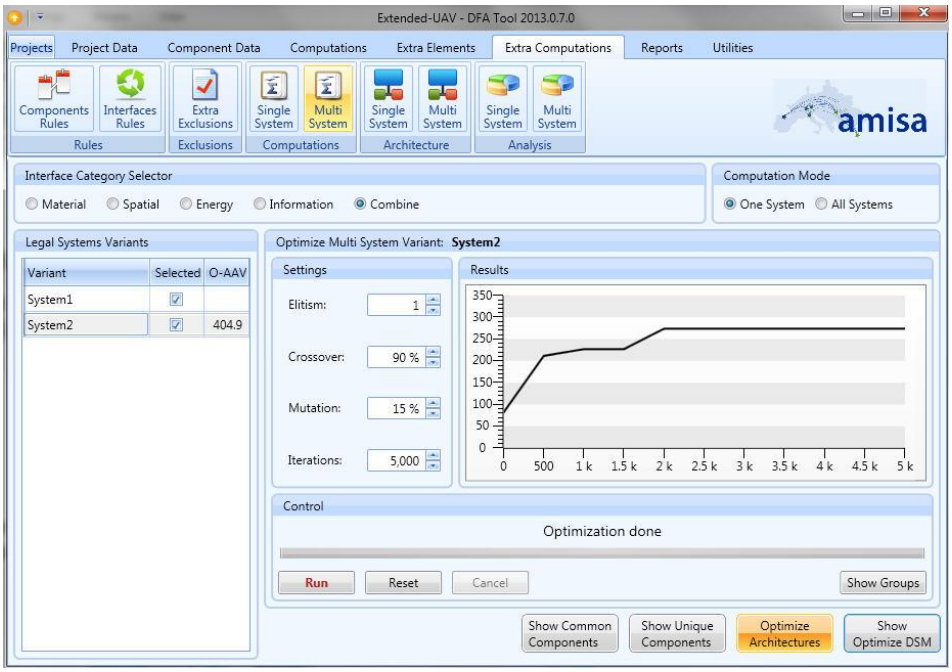
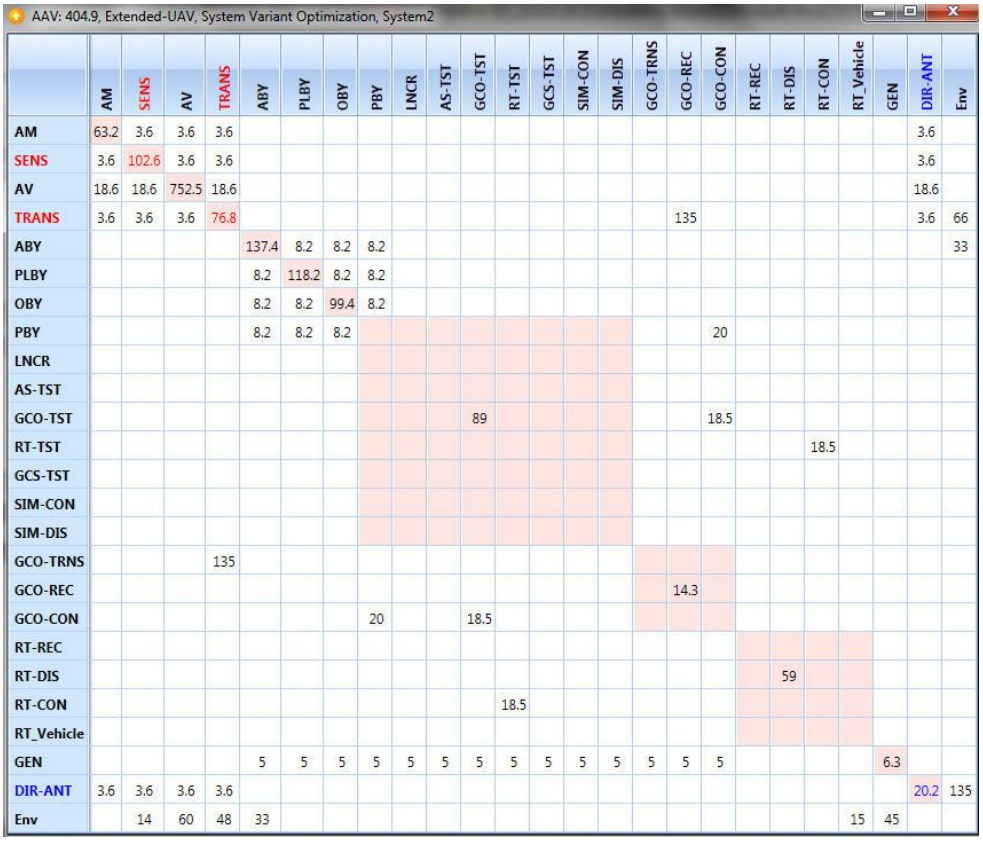


Figure 7-13 - Multi system optimization GUI - Variant UAV system

The optimized DSM of the UAV variant system under Multi system optimization is depicted in Figure 7-14.



	AM	SENS	AV	TRANS	ABY	PLBY	OBY	PBY	LNCR	AS-TST	GCO-TST	RT-TST	GCS-TST	SIM-CON	SIM-DIS	GCO-TRNS	GCO-REC	GCO-CON	RT-REC	RT-DIS	RT-CON	RT_Vehicle	GEN	DIR-ANT	Env
AM	63.2	3.6	3.6	3.6																				3.6	
SENS	3.6	102.6	3.6	3.6																				3.6	
AV	18.6	18.6	752.5	18.6																				18.6	
TRANS	3.6	3.6	3.6	76.8													135							3.6	66
ABY					137.4	8.2	8.2	8.2																	33
PLBY					8.2	118.2	8.2	8.2																	
OBY					8.2	8.2	99.4	8.2																	
PBY					8.2	8.2	8.2											20							
LNCR																									
AS-TST																									
GCO-TST											89							18.5							
RT-TST																					18.5				
GCS-TST																									
SIM-CON																									
SIM-DIS																									
GCO-TRNS				135																					
GCO-REC																	14.3								
GCO-CON								20			18.5														
RT-REC																									
RT-DIS																				59					
RT-CON												18.5													
RT_Vehicle																									
GEN					5	5	5	5	5	5	5	5	5	5	5	5	5	5					6.3		
DIR-ANT	3.6	3.6	3.6	3.6																				20.2	135
Env		14	60	48	33																	15	45		

Figure 7-14 - Optimized DSM of the UAV variant system (Multi system)

The user can click the "Show Groups" button in order to see the exclusive optimization groups (Figure 7-15). Each group is mutually exclusive from the other group for the purpose of DFA optimization.

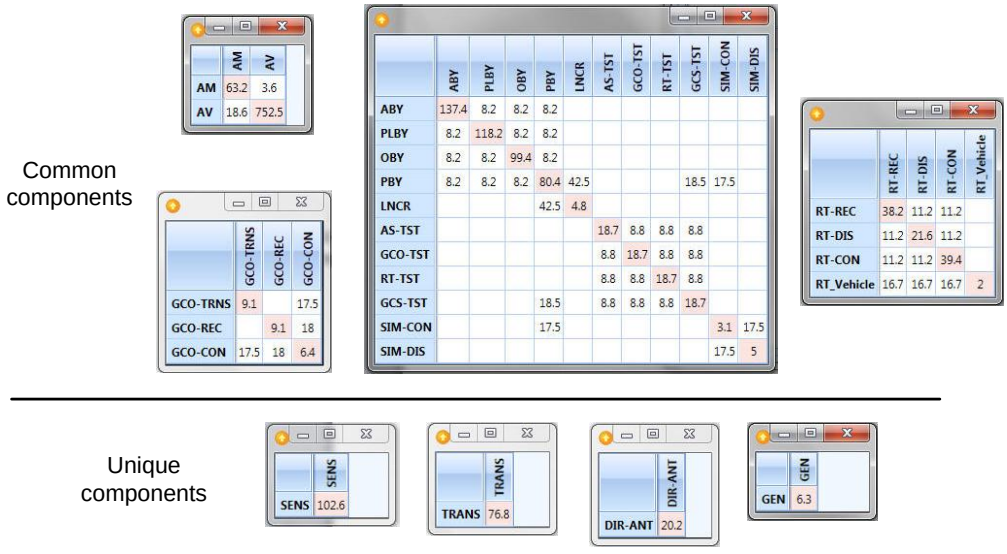


Figure 7-15 - Exclusive optimization groups (Multi system)

7.4 Architecture

The user can generate graphical charts of architectures for each of the defined system variants.

7.4.1 Single system

Under single-system approach, the user can utilize the "Optimization Mode" to select between generating non-optimized or optimized architecture charts. The details of generating such charts are provided in section 3.5-Architecture and section 5.1.6-Optimize architecture.

Figure 7-16 depicts an edited "Information" architecture of the UAV system-2 variant.

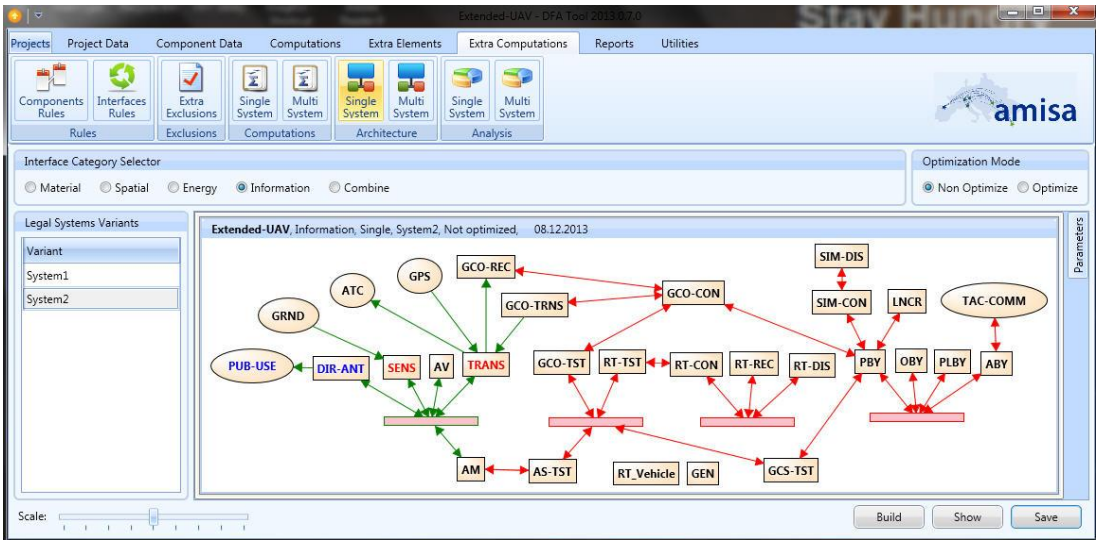


Figure 7-16 - Edited "Information" architecture - UAV system-2

Figure 7-17 depicts an edited "Energy" architecture of the UAV system-2 variant.

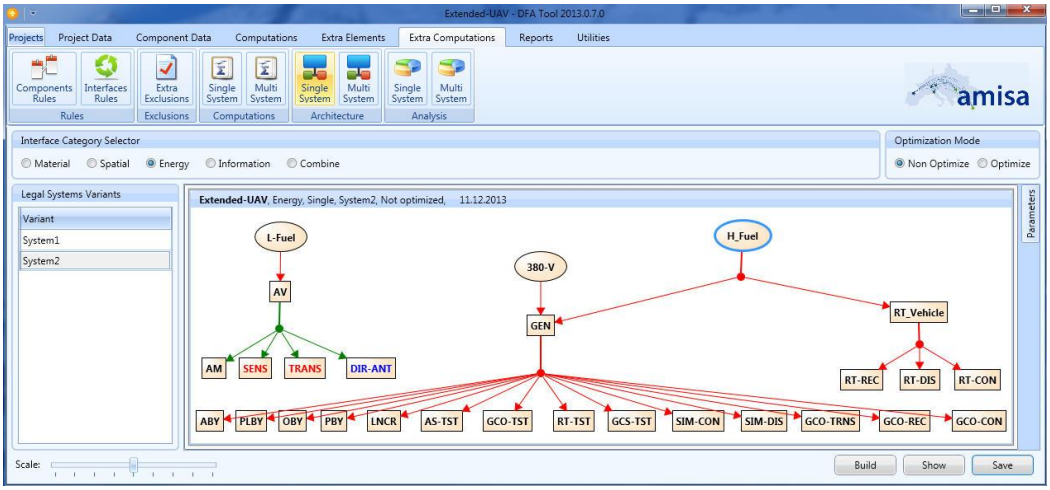


Figure 7-17 - Edited "Energy" architecture - UAV system-2

Figure 7-18 depicts an edited "Combine" architecture of the UAV system-2 variant.

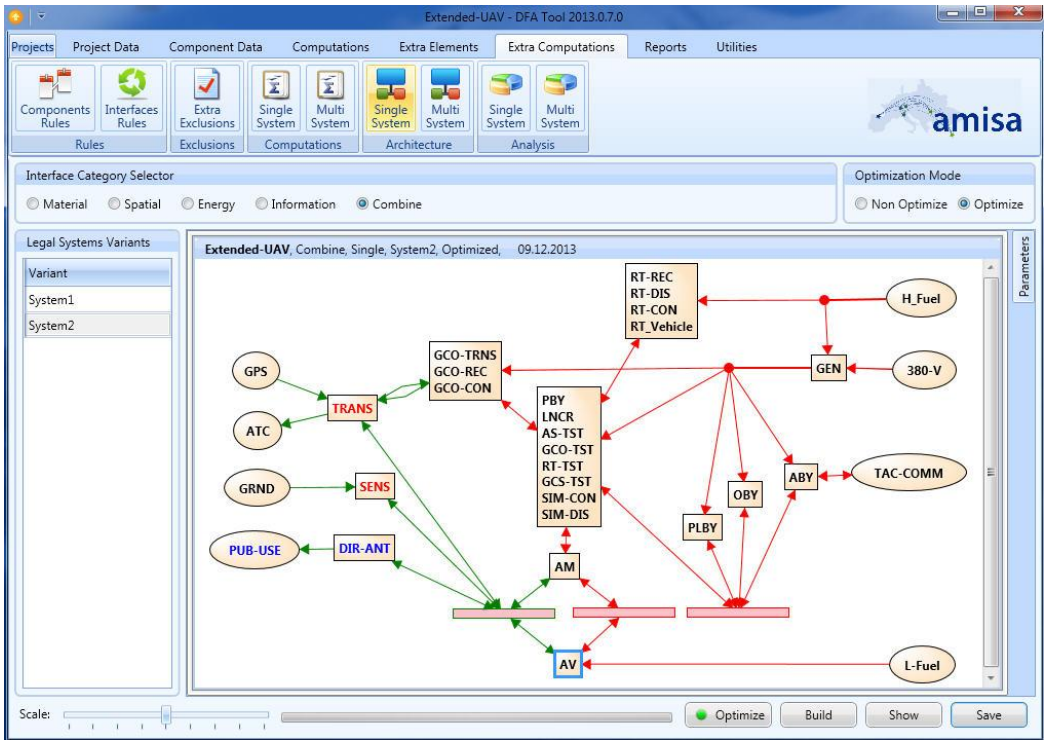


Figure 7-18 - Edited "Combine" optimized architecture - UAV system-2

7.4.2 Multi system

Under Multi-system approach, the user firstly selects the family participants in the optimization process. Only components that are common to the entire participating family are eligible to participate in the optimization process. Then the user can generate optimized architectures of any system variant (under multi-systems variants rules). The details of generating such charts are provided in section 5.1.6-Optimize architecture.

Figure 7-19 depicts an optimized "Information" architecture of the UAV system-2 variant under Multi-systems variant rules.

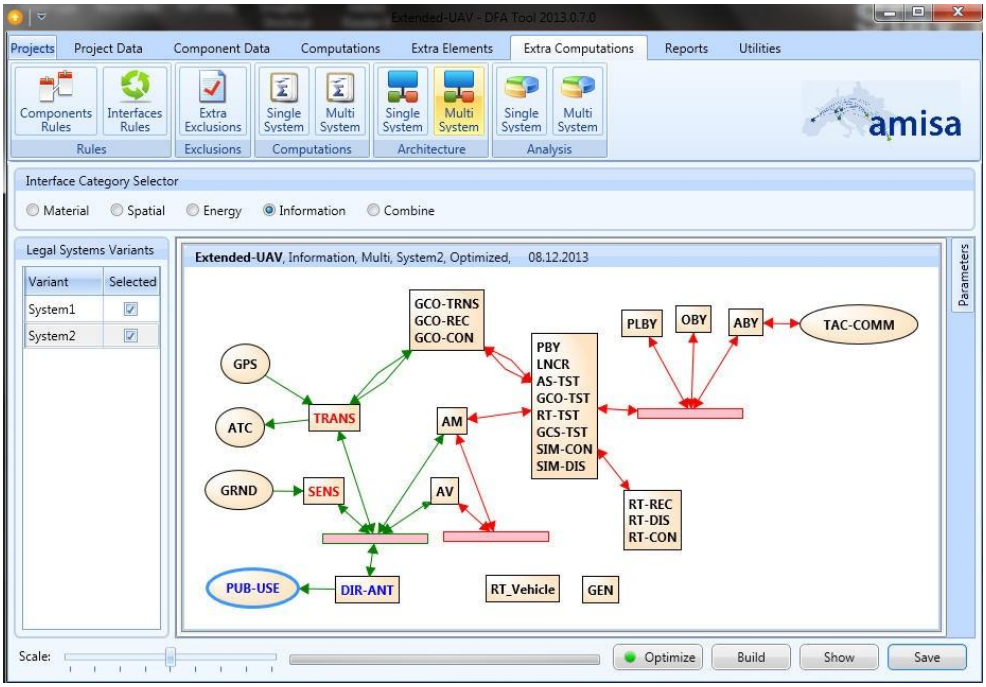


Figure 7-19 – Multi-System mode - Optimized "Information" architecture - UAV system-2

7.5 Analysis

The user can perform sensitivity analysis for each individual variant of the system family as standalone (Single mode) or as a combined product family (Multi mode). The details of this capability are provided in section 5.3 - Sensitivity analysis. The system architecture sensitivity analysis is based on the assumption that estimating Option Values (OVs) and Interfaces Costs (ICs) may be inexact. Therefore, users may like to perform sensitivity analysis in which different architectures may be generated as a result of changing slightly the expected OCs and ICs. This includes.

7.5.1 Explore system architectures space

The user can explore the space of system architectures by running the sensitivity analysis for a single iteration. This includes:

1. Conduct exploration (See Section 5.3.1.1)
2. Show exploratory lattices (See Section 5.3.1.2)

7.5.2 Conduct sensitivity analysis

The user can optimize a set of system architectures, using different combinations of OV and IC values. This includes:

1. Optimize the AAV set under Single-mode and Multi-mode (See Section 5.3.2.1)

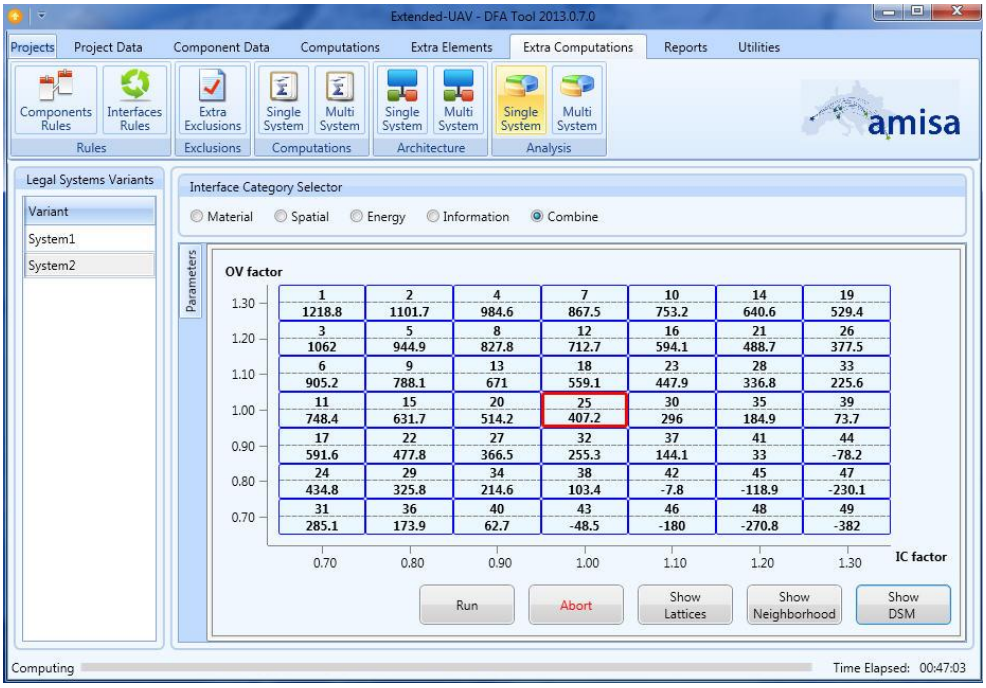


Figure 7-20 - Optimized sensitivity analysis – System-2 (Single-mode)

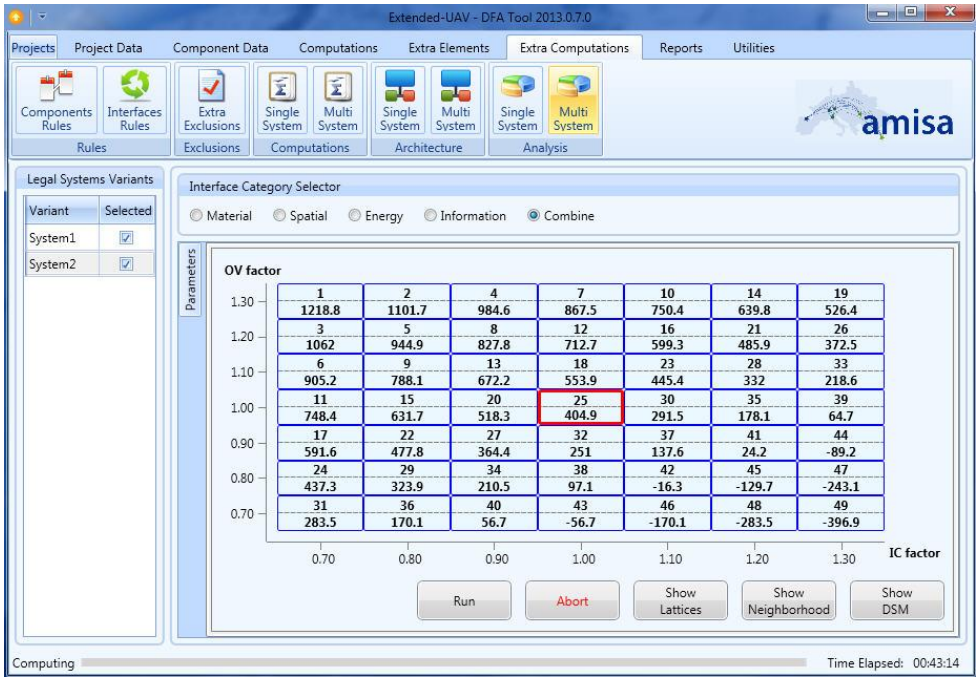


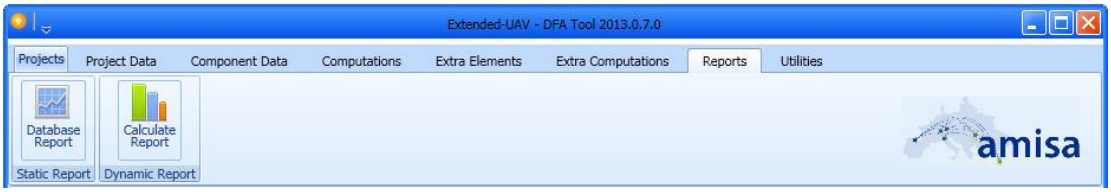
Figure 7-21 - Optimized sensitivity analysis – System-2 (Multi-mode)

2. Show lattices (See Section 5.3.2.2)
3. Show neighborhood (See Section 5.3.2.3)

4. Show DSM (See Section 5.3.2.4)
5. Analyze lattices chart (See Section 5.3.2.5)
6. Perform Convergence analysis (See Section 5.3.2.6)

8. Reports

The user can generate two sets of reports within the DFA-Tool: (1) Database reports and (2) Calculation reports. The calculations reports were not implemented (see below).



8.1 Database reports

Generate reports of all database information. Each element of the database may be extracted and be displayed on the screen and/or generated as a report. Each report encompasses data associated with a relevant DFA-Tool icon. In addition, each report may be produced in any of the following formats: RTF, PDF, Excel-97, CSV, TIFF and Web-Archive. Figure 8-1 depicts the report generation GUI with currently available reports list. Figure 8-2 depicts a portion of an interface report.

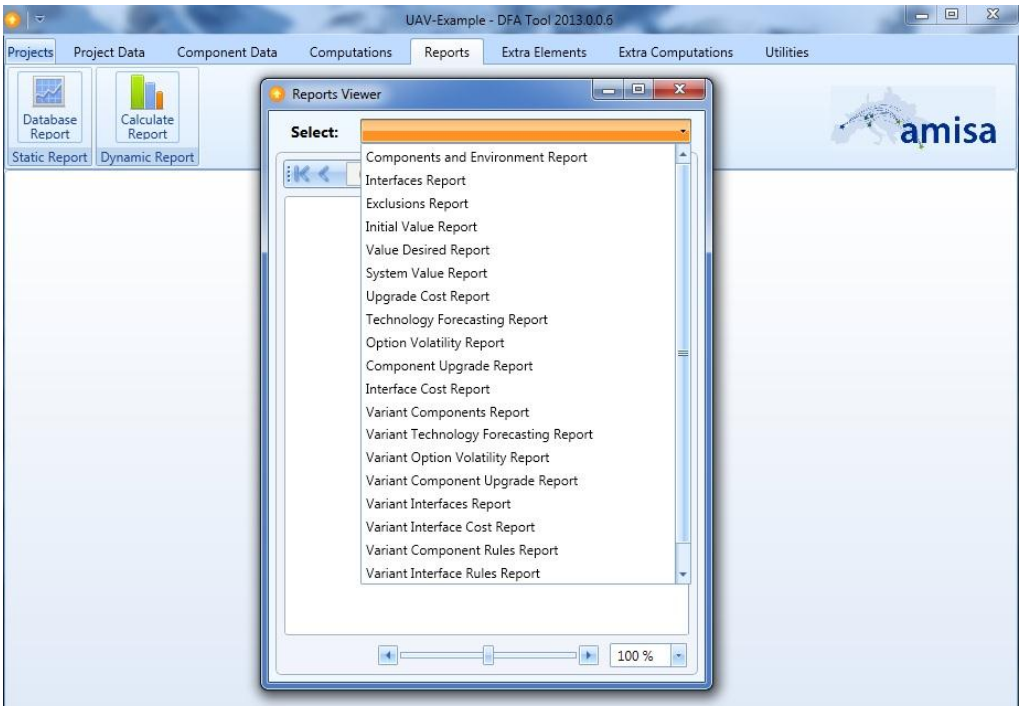
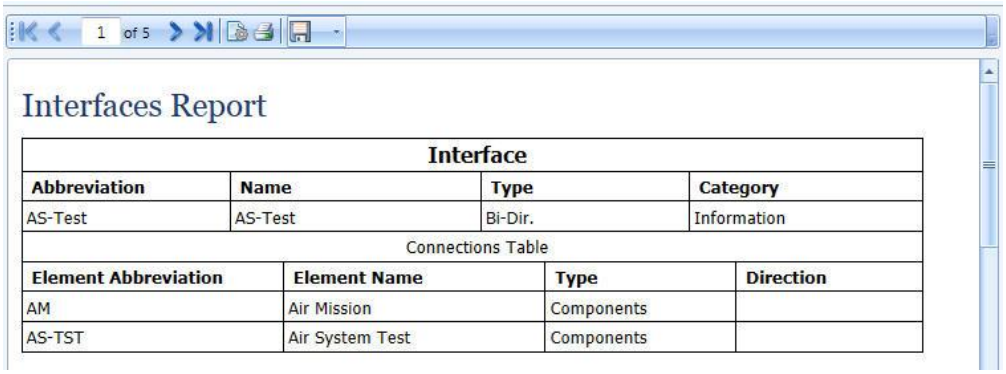


Figure 8-1 – Report generation GUI



1 of 5

Interfaces Report

Interface			
Abbreviation	**Name**	**Type**	**Category**
AS-Test	AS-Test	Bi-Dir.	Information

Connections Table

Element Abbreviation	Element Name	Type	Direction
AM	Air Mission	Components	
AS-TST	Air System Test	Components	

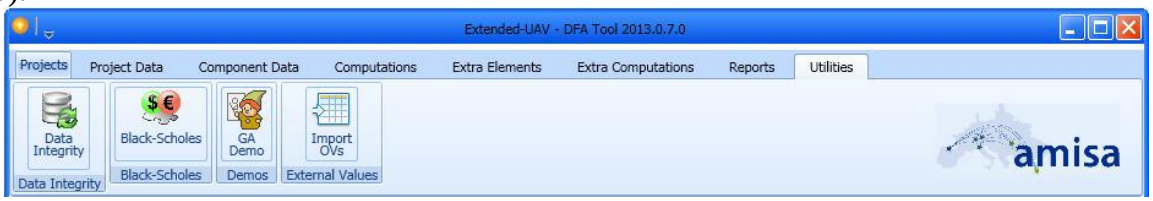
Figure 8-2 – Portion of an interface report

8.2 Calculate reports (not implemented)

Generate reports of all DFA-Tool computations.

9. Utilities

The user can perform the following DFA-Tool utilities: (1) Database integrity, (2) Black-Scholes investigation, (3) Genetic Algorithm Demonstration and (4) Acquire External Option Values (see below).



9.1 Database integrity

Figure 9-1 depicts the DFA-Tool database integrity verification GUI. The software checks the database integrity of the currently running project and identifies any irregularities or missing data.

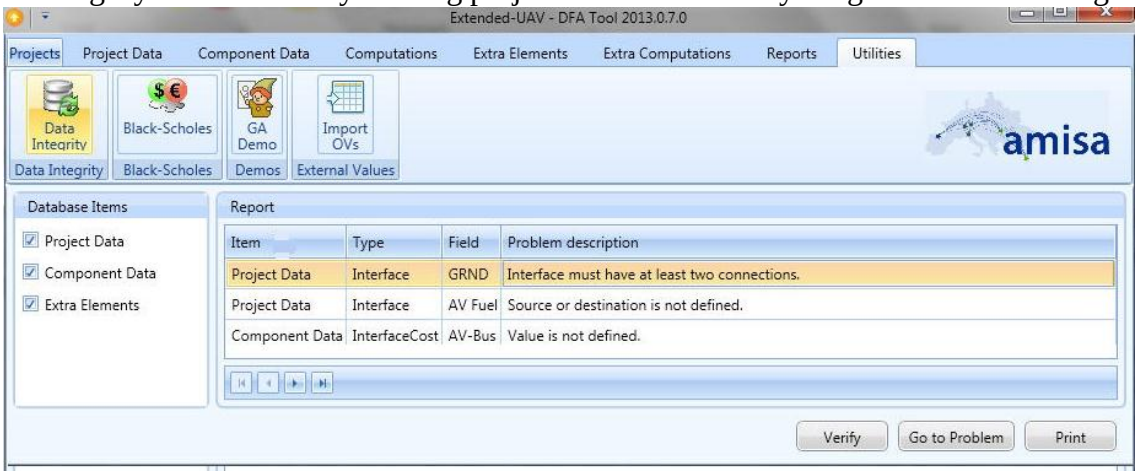


Figure 9-1 – Database integrity verification GUI

9.1.1 Procedure

The procedure to check database integrity involves the following:

- Step-1: Click on the Data Integrity in the Utilities Tab.
- Step-2: All types of DB verification types (i.e. Project Data, Components Data and Extra Elements) are selected as a default. The user may select a subset if desired.
- Step-3: Click on the "Verify" button. The tool will generate a DB problem report and identify all DB problems associated with the selected items. For each database problem, the report identifies the relevant: (1) Item, (2) Type, (3) Field and (4) a description of the database problem. If the database contains no problem, the tool will indicate a correct database.
- Step-4: The user can select a line in the report table and then click the "Go to Problem" button. The tool will close the current entry and will transit to the area where the problem was identified.
- Step-5: The user can click the "Print" button and the tool will generate an image of the DB problem table.

9.1.2 Example

In the example depicted in Figure 9-1 the user maintained the default to verify all types of the database. Three errors were detected The "GRND" interface has only one connection, the "AV Fuel" interface has improper definition of the required Source/Destination and the "AV-Bus" has improper definition of its interface cost.

9.2 Black-Scholes investigation

The Black-Scholes investigation GUI is depicted in Figure 9-2. The user can investigate the expected future value distribution of a selected component using the Black-Scholes equation.

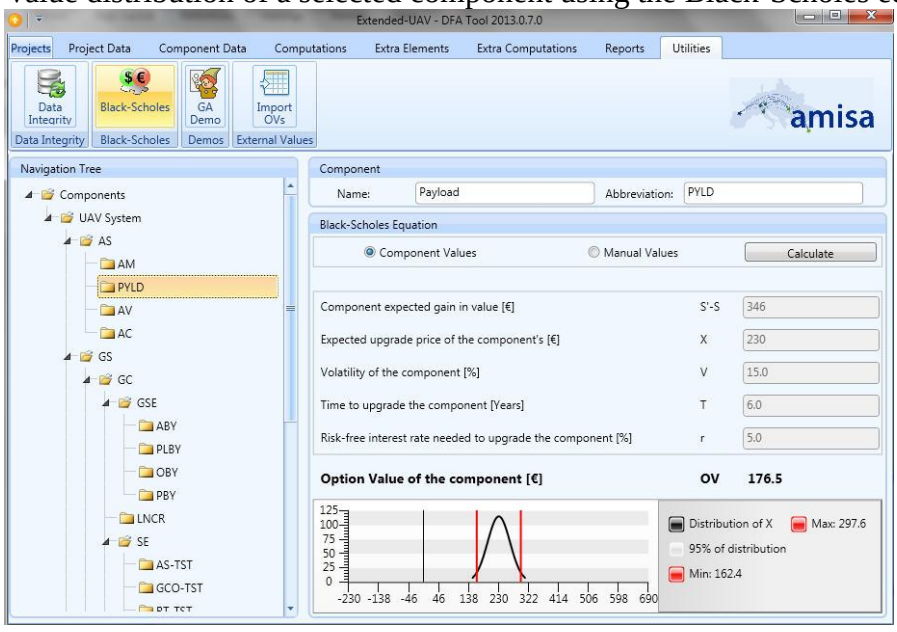


Figure 9-2 - Black-Scholes component's computation

9.2.1 Procedure

The procedure to compute the Option Price for a given component is carried out following these steps:

- Step-1: Click on the relevant component in the navigation tree in order to select the component of interest. If all data needed for the calculations is define then the Option Price (OP) will be calculated and the expected distribution of the update price (X) will be plotted. In addition the range within which 95% of X lies will be displayed.
- Step-2: In order to investigate the effects of different Black-Scholes parameters, click on the "Manual values" radio button, set the desired Black-Scholes parameters to desired values and click the "Calculate" button. Please note that these manual values do not affect the actual values residing in the database.

9.2.2 Example

In the example depicted in Figure 9-2 the Black-Scholes parameters associated with the ABY (Analysis Bay), are: S=400€, X=820€, V=30%, T=5 Years, r=3%. The DFA-Tool computes the Option Price (OP=38.1€). The upgrade distribution window shows that 95% of the expected upgrade price lies in the [338€ - 1302€] range.

9.3 Genetic Algorithm demonstration

Figure 9-3 depicts a Genetic Algorithm (GA) utility, demonstrating AMISA optimization concepts (using a 10 X 10 synthetic system).

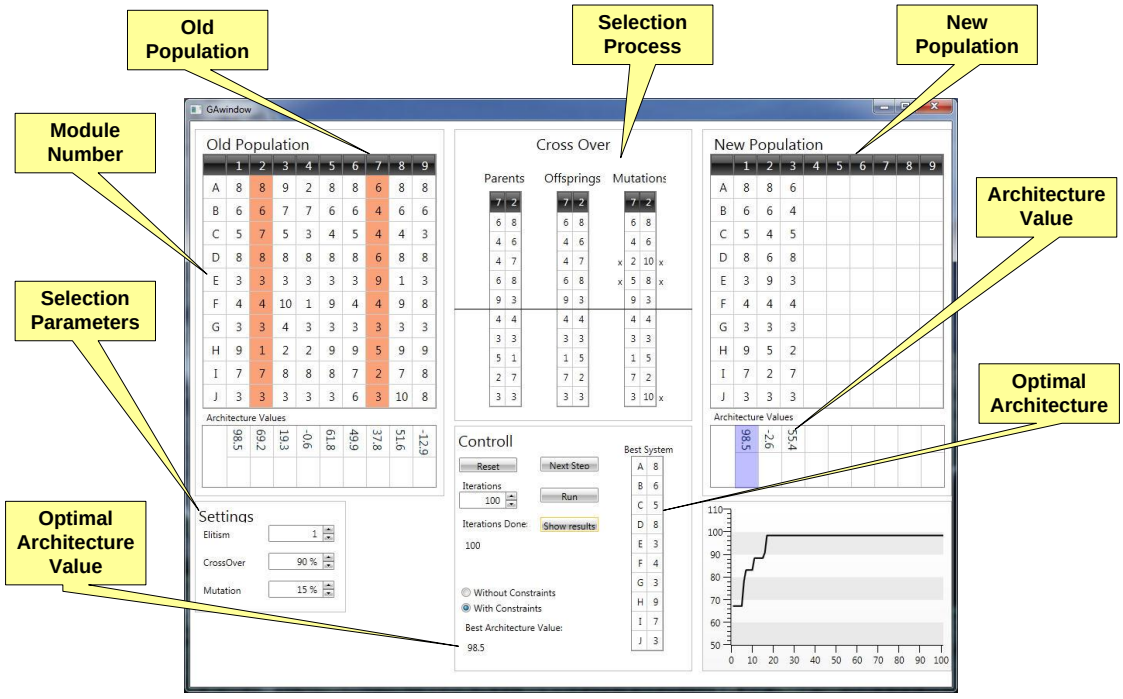


Figure 9-3 – Optimization (by means of Genetic Algorithm)

9.4 Acquire external Option Values

Another method and tool for generating Option Values, using definitions of S-Curves and Monte-Carlo simulations, has been demonstrated within AMISA. The DFA-Tool is capable of acquiring such externally generated Option Values and utilizing them in lieu of the internally computed OVs. Figure 9-4 depicts a block diagram of the relevant DFA-Tool software implementing the external OVs handling. As can be seen, the external OVs are fed into the database by means of an External OVs XML file.

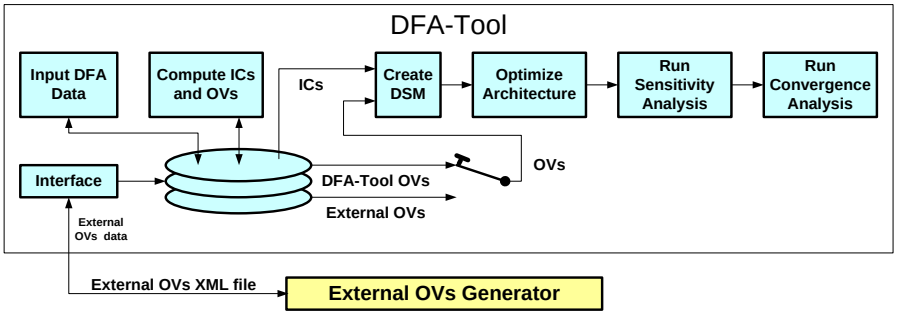


Figure 9-4 – External OVs handling – DFA-Tool

Figure 9-5 depicts an external OVs XML file capturing a synthetic example of external OVs associated with the UAV system.

```
<?xml version="1.0" encoding="utf-8" standalone="yes"?>
<Project ProjectName="Extended-UAV">
    <OVs>
        <Element Abbreviation="AM" EXT_OV="10" />
        <Element Abbreviation="PYLD" EXT_OV="20" />
        <Element Abbreviation="AV" EXT_OV="30" />
        <Element Abbreviation="AC" EXT_OV="40" />
        <Element Abbreviation="ABY" EXT_OV="50" />
        <Element Abbreviation="PLBY" EXT_OV="60" />
        <Element Abbreviation="OBY" EXT_OV="70" />
        <Element Abbreviation="PBY" EXT_OV="80" />
        <Element Abbreviation="LNCR" EXT_OV="90" />
        <Element Abbreviation="AS-TST" EXT_OV="100" />
        <Element Abbreviation="GCO-TST" EXT_OV="90" />
        <Element Abbreviation="RT-TST" EXT_OV="80" />
        <Element Abbreviation="GCS-TST" EXT_OV="70" />
        <Element Abbreviation="SIM-CON" EXT_OV="60" />
        <Element Abbreviation="SIM-DIS" EXT_OV="50" />
        <Element Abbreviation="GCO-TRNS" EXT_OV="40" />
        <Element Abbreviation="GCO-REC" EXT_OV="30" />
        <Element Abbreviation="GCO-CON" EXT_OV="20" />
        <Element Abbreviation="RT-REC" EXT_OV="10" />
        <Element Abbreviation="RT-DIS" EXT_OV="100" />
        <Element Abbreviation="RT-CON" EXT_OV="200" />
        <Element Abbreviation="RT_Vehicle" EXT_OV="50" />
        <Element Abbreviation="GEN" EXT_OV="80" />
    </OVs>
</Project>
```

Figure 9-5 – A synthetic External OVs XML file example

Acquisition of external OVs GUI is depicted in Figure 9-6. When the user clicks on the External OVs button, the DFA-Tool display a list of components leaf as defined in the database. In addition their current external values are also displayed. The tool automatically assigns zeros to all OVs not otherwise defined. The user may select an appropriately constructed XML file and then click the Load and Save button. The user will be notified if any error was found in the external OVs XML file. Also note that the user can modify the external OVs database by means of an external OVs XML file only.

A special interface mechanism observes the following rules: (1) The input to the tool must be in XML format, (2) During acquisition, the project name in the XML list must match the current

project name defined in the DFA-Tool, (3) Only valid names of leaf components, existing in the DFA-Tool, are be considered (4) only valid (positive, real numbers) OVs values are accepted, (5) OVs associated with erroneous (incorrect) leaf components names will be assigned zeros. During normal operations, the user will be able to select internal OVs (generated by the DFA-Tool) or the external OVs. The selected data will be used to compute DSMs, optimize architectures, perform sensitivity analysis as well as run convergence analysis.

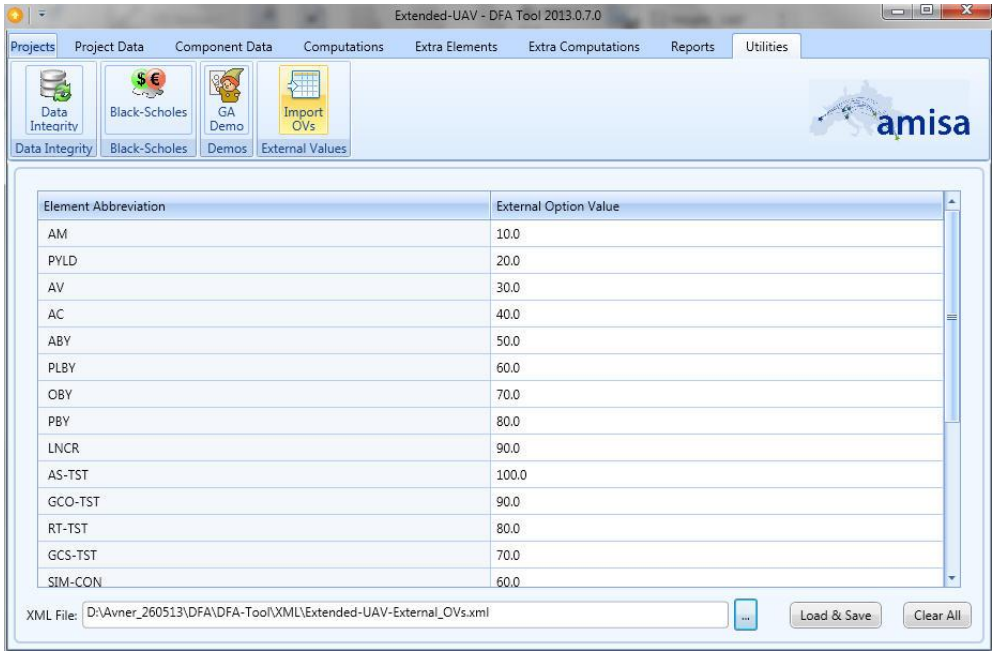


Figure 9-6 - External OVs acquisition GUI – an example